

sirable, to form them wholly by upsetting. Properly, they should be made either by partial upsetting and partial drawing down, or wholly by drawing down, according to the stock that happens to be used. (2) When the bosses are relatively large and the eyes relatively small (Fig. 122) and the rods are several

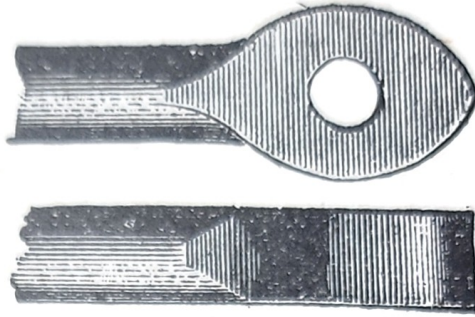


Fig. 122.—Small Tie Rod.

feet in length, as in the tie rods of roofs, they may be forged from the solid, apart from their rods, and welded on. (3) When the eyes are large (Fig. 123),

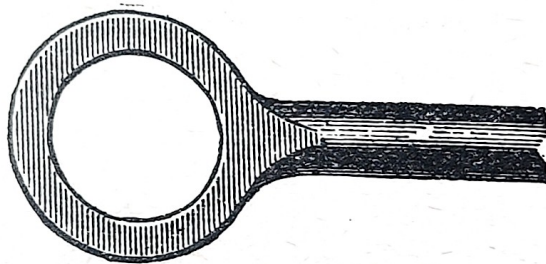


Fig. 123.—Large Tie Rod.

as in the truss and tie rods of bridges, jibs of traveling cranes, etc., they may be formed by bending round and welding the iron, and usually also by welding the eyes to their rods.

All these will be finished after rough hammering by the aid of the hollow top and bottom tools or swages, operating on the curved edges (*a*, Fig. 121); by the flatter and sledge on the flat faces *b*, and by the fullering tool around the neck *c*. In repetition work the eyes would be finished in a pair of cast-iron

dies, like Figs. 124 and 125; the former gives the finished curvature to the edges *a* and the fullered neck *c*, whilst the latter completes the flat faces *b* in succession. The eye *d* is punched while the boss *B* lies in the die, the core falling down into the hole *A*, a trifle larger than the punch. The boss is beaten into the dies with the sledge, or preferably under the drop, or the steam hammer.

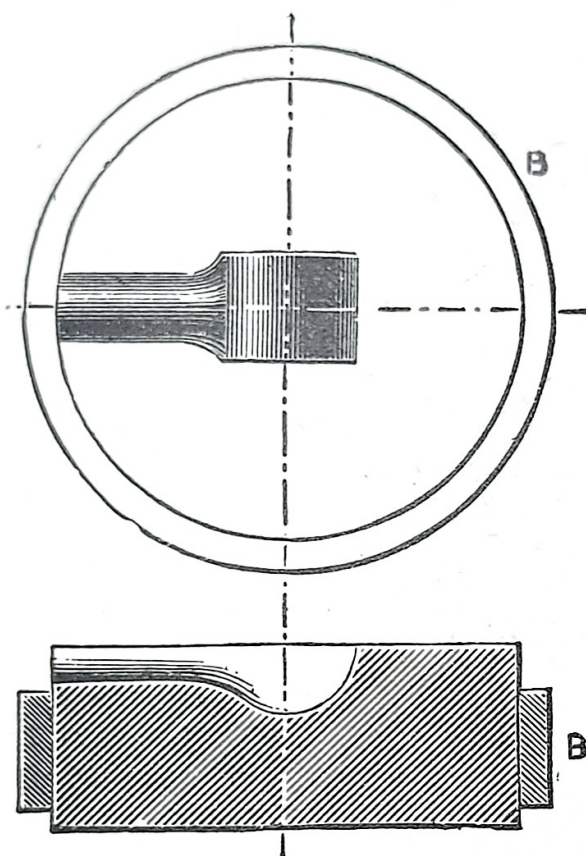


Fig. 124.—Die Block

These blocks are made of square as well as of circular form, but the latter is to be preferred, because of the greater ease experienced in fitting and shrinking on the bond shown in Figs. 124 and 125, where *B* is a wrought-iron bond shrunk on to prevent the cast iron from bursting from the concussion to which it is subject.

Dies like this are often made in pairs, top and bottom being coupled with pins for use under the steam hammer.

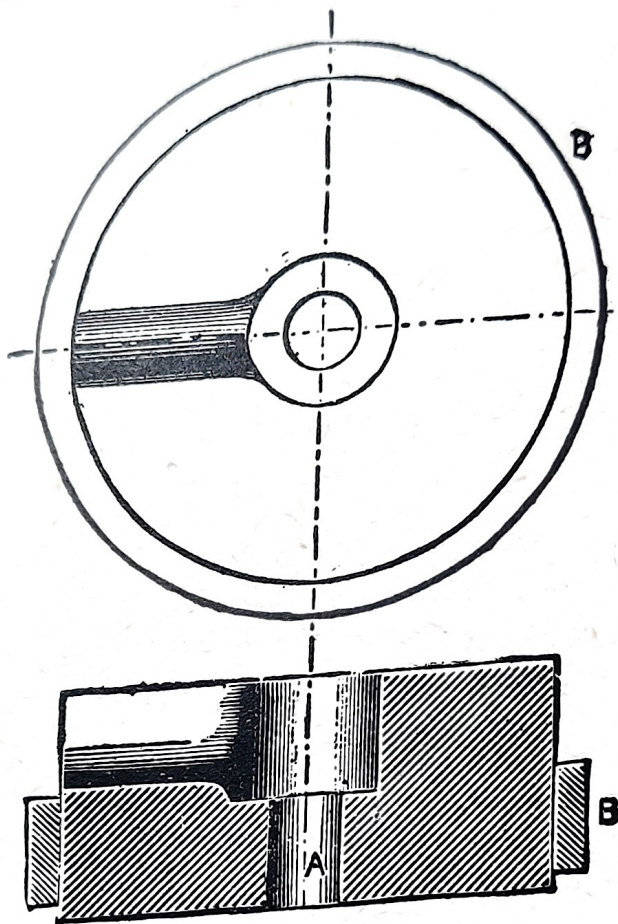


Fig. 125.—Die Block.

(2) The bosses are made from bar iron of their own dimensions, and a sufficient length is drawn down—say from three to six inches—to permit of

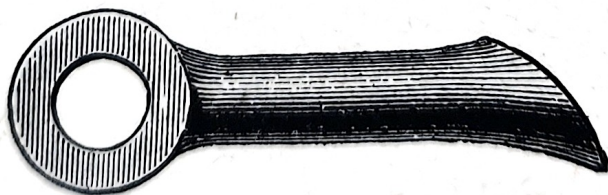


Fig. 126.—Boss End Scarfed for Welding.

making, with the long plain body of the rod, a scarfed welding joint (Fig. 126).

(3) The eye is bent round and welded, forming a short solid shank, which is then scarfed and fullered for welding, like Fig. 127. Or it is bent round to

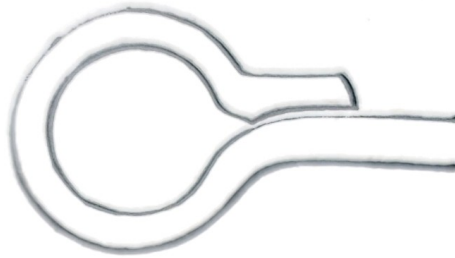


Fig. 127.—Eye bent for Welding.

form a tongued joint (Fig. 128), in which a wedge-like end is fitted into a corresponding cleft, and

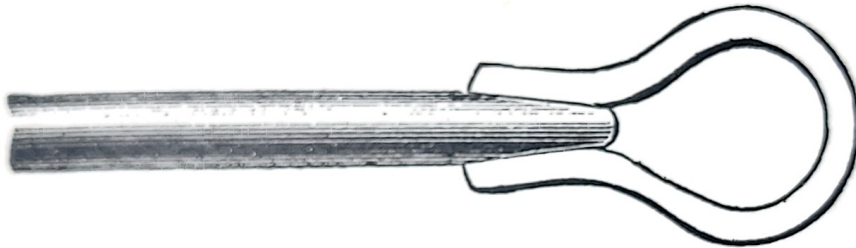


Fig. 128.—Tongued Joint.

welded. This is supposed to be stronger than the plain scarf, and is often used for iron of heavy section.

Fig. 129 shows a tongue joint in solid bars. To



Fig. 129.—Solid Tongued Joint.

make it, first upset both ends; then for the tongue A set in a fullering tool on opposite sides of the upset portion (Fig. 130, a). Then, by hammering, the end will be tapered down until it has the appearance of Fig. 129, A. For the recess B, nick the other upset end inwards with a chisel, and open out sufficiently with

a wedge. This will spread the end more, as well as open it out; and this spreading out is an advantage, because it gives plenty of metal for welding and swaging down to finished dimensions. The tongue joint is then made in the usual way by heating both ends to the welding heat, and when assured that the faces are free from dirt and scale, closing them together, first with the hammer, and finishing them

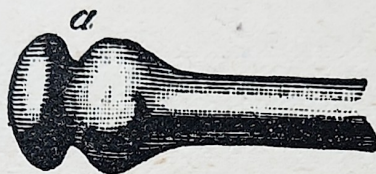


Fig. 130.—Fullered End.

with the top and bottom swages. To ensure union at the termination of the tongue, the first blows should be given endwise. These may be given while the work is in the fire, provided the fire is clean, and the joint cleansed by throwing sand into the fire over the work. When the circumference of the joint is being hammered, the angular swages may be used to better advantage than by merely laying the work upon the anvil.

Levers of the general form shown in Fig. 131, but

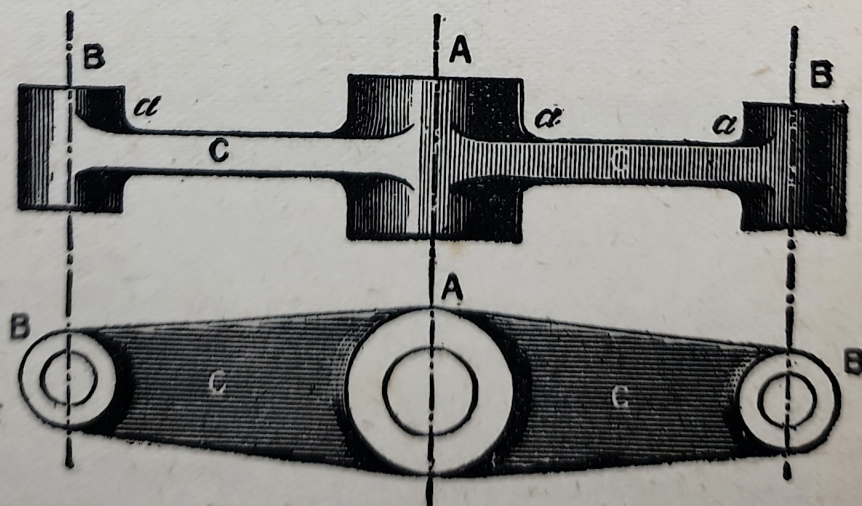


Fig. 131.—Double-ended Lever.

variously proportioned, are very common. The methods of forging them will be modified by circumstances. They may be drawn wholly from the solid, or partly drawn and partly welded—seldom, however, being upset.

A lever of the proportions shown in Fig. 131 would, in general, be formed wholly by drawing down. A bar of iron, having a sectional area about equal to that of the central boss A, is selected. First, a fuller is driven in on opposite sides, as at *a, a, a, a* (Fig. 132). Then the bar is drawn down roughly from the fuller nicks to the ends, until the ends are reduced to an area A (Fig. 132), suitable for the smaller end boss B (Fig. 131). Again the fuller is driven in at

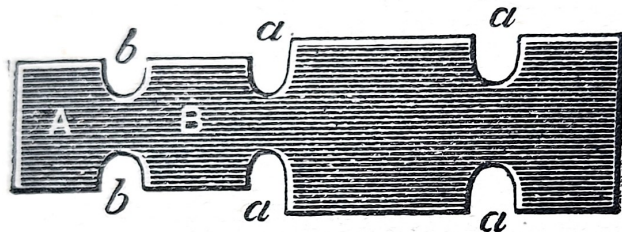


Fig. 132.—Fullered Lump.

b, b (Fig. 132), and then the intermediate portion B is reduced by fullering or by hammering until the required thickness of the web (*c* in Fig. 131) is nearly reached. The blows are delivered on sides and faces alternately, drawing the sides to the tapered form seen in the plan view, as well as the webs to thickness.

There is no attempt at finish just yet, for the centers of the bosses are probably not the correct size, and it will very likely happen that some further drawing down, or even some upsetting, will be required before the boss lumps will be sufficiently near to correct centers, to permit of their finishing to the required dimensions. Rough measurement will be taken from time to time with the rule, or with some form of gauge.

At this stage the lever will resemble Fig. 133, with square lumps at center and ends of the webbed portion. To hammer these bosses into a circular form

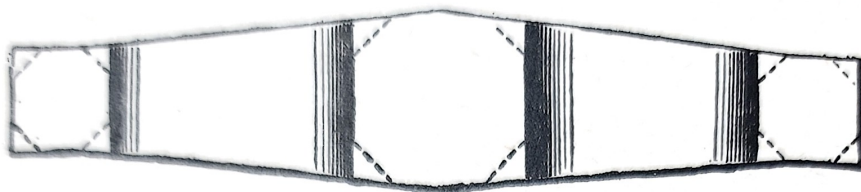


Fig. 133.—Lever Roughly Forged.

would involve much labor and several heats, so the corners are cut off with a hot set, as shown by the dotted lines. When a boss is small, four corners only are cut off; when large, eight, or even more.

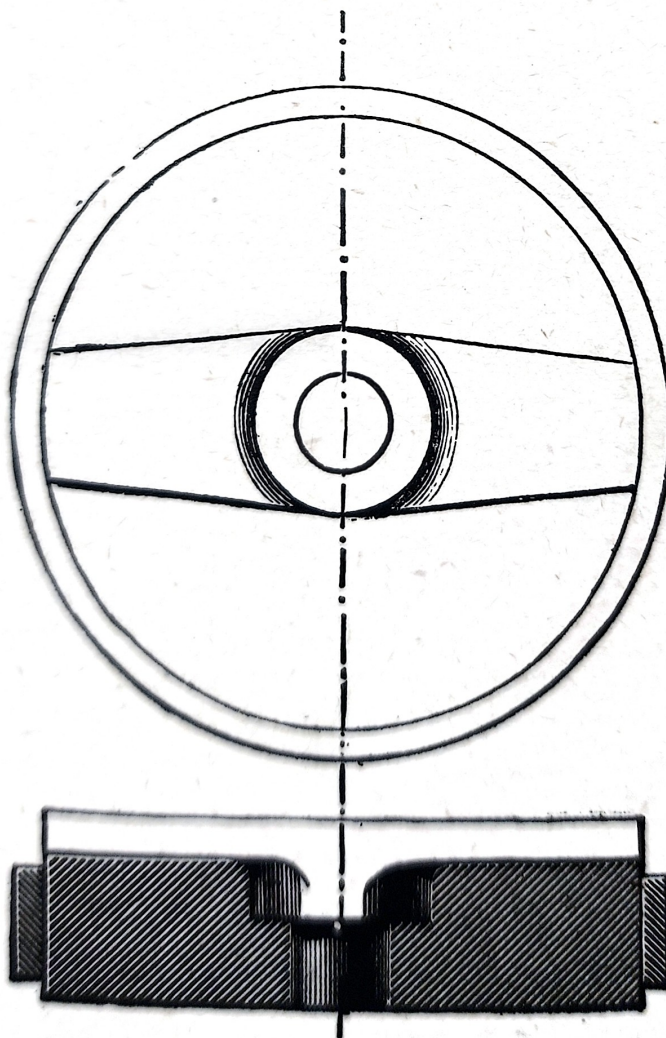


Fig. 134.—Die Block.

The set is driven perpendicularly first, but not right down to the web, it stops at the radius or hollow—and then horizontal cuts are made to meet the perpendicular ones, and so the boss is rudely chiselled to a circular form. Then the hammer, and afterwards the hollow swage, are used to give a more circular

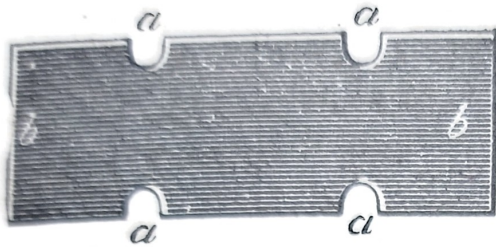


Fig. 135.—Fullered Lump.



Fig. 137.—Boss Lump prepared for Dabbing On.

form to the bosses; and the hollows shown at *a, a*, in Fig. 131, are shaped with a hollow fuller. Thus bosses can be made fairly shaped, but not perfectly true. In repetition work dies are used; that for the end bosses would be like Fig. 125, and these (B in

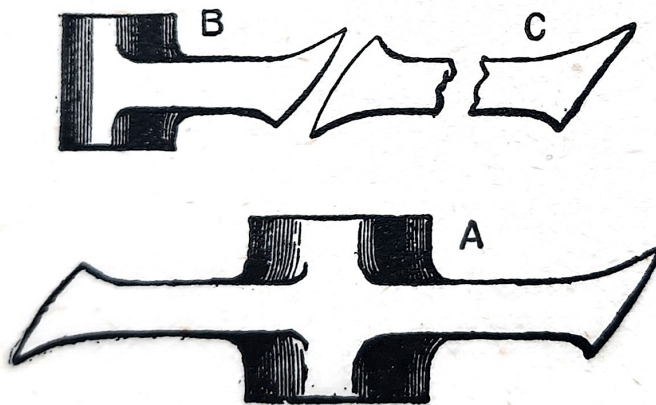


Fig. 136.—Bosses and Rod Scarfed for Welding.

Fig. 131) would be hammered into a recess in the middle of the die, and the web would rest in a recess reaching from the center to the outside. The die for the center boss is shaped like Fig. 134. Bosses finished thus are so true that they can be left without subsequent turning, brightening on the emery wheel giving sufficient finish.

For a lever anything over a foot in length, it

would be easier to take separate pieces of bar iron for the web, and separate pieces for the bosses, and weld them together. Thus a lump (Fig. 135) would be taken for the central boss, and set in with the fuller at *a, a*, and drawn down at each end, *b, b*, leaving the extreme ends rather thicker than the intermediate portion, *A*, Fig. 136, in order to form scarfed joints for welding. The end bosses, *B*, would be similarly prepared, and all welded to the webs, *C*, which is also upset and scarfed. The shaping and finishing of the bosses are most conveniently done before the welding up.

Another way is to weld or "dab" bosses on the web; these are cut off an iron rod of suitable diameter. The red-hot boss (Fig. 137) is roughed

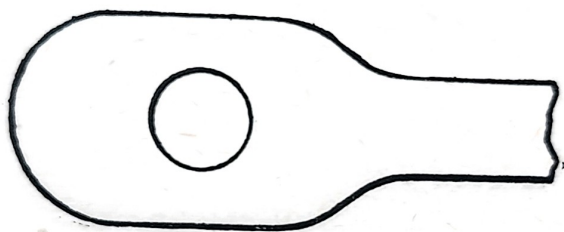


Fig. 138.—Tie Rod End.

with a corner of the chisel, which is held diagonally and struck with a hammer. These roughings assist the union of the welded surfaces, which being then raised to a welding heat, the flat bars and the bosses are made to adhere by a few hammer blows. The thinner the web, the more intimate and secure the weld.

When forging articles in this way, it will be necessary to test the parallelism and the rectangular form, and the winding of the various parts. Forgings are apt to develop inaccuracy quickly while the metal is soft, so the smith employs the eye in these early stages of the work, and squares, and calipers, and straight-edges as it becomes cooler.

Large tie-rod ends (Fig. 138) are always welded to their rods. A rectangular lump is drawn down (Fig.

139) at the end A to a trifle larger than the rod, and scarfed for welding. The corners B are rounded by first cutting off the angles with the hot set, and then by rounding off with the chisel shown at Fig. 145.

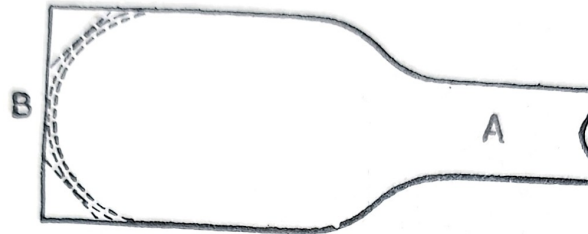


Fig. 139.—Rough Forging for Tie Rod End.

In these rods the eyes, being large, are usually punched first, and frequently they are reamed out afterwards. Such large holes are punched with difficulty under the sledge, but easily under the steam hammer. Fig. 140 shows the arrangement employed:

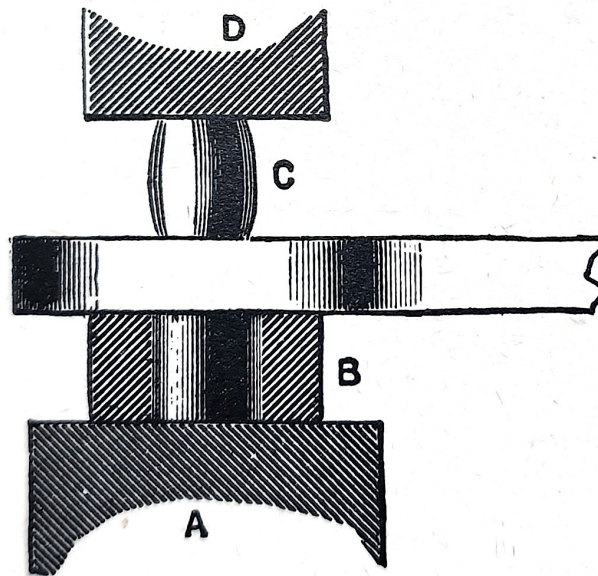


Fig. 140.—Punching Hole in Tie Rod End.

A is the anvil of the steam hammer, and upon this rests the bolster, B, which must be sufficiently large to give proper bearing support to the eye, and its hole must be a trifle larger, but not much larger than that of the punch C. Two or three blows of the hammer or tup, D, will drive the punch through; this is

slightly bellied in order to squeeze the metal, and also to clear itself of the hole easily.

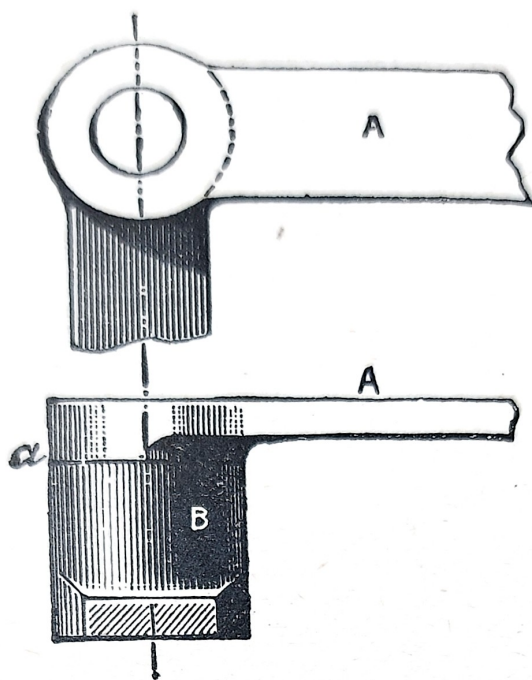


Fig. 141.—Lever Arms.

After rounding the edges and punching the hole, but before the bar is quite cool, the flatter will be used to smooth over the edges that have been slightly upset during these processes.

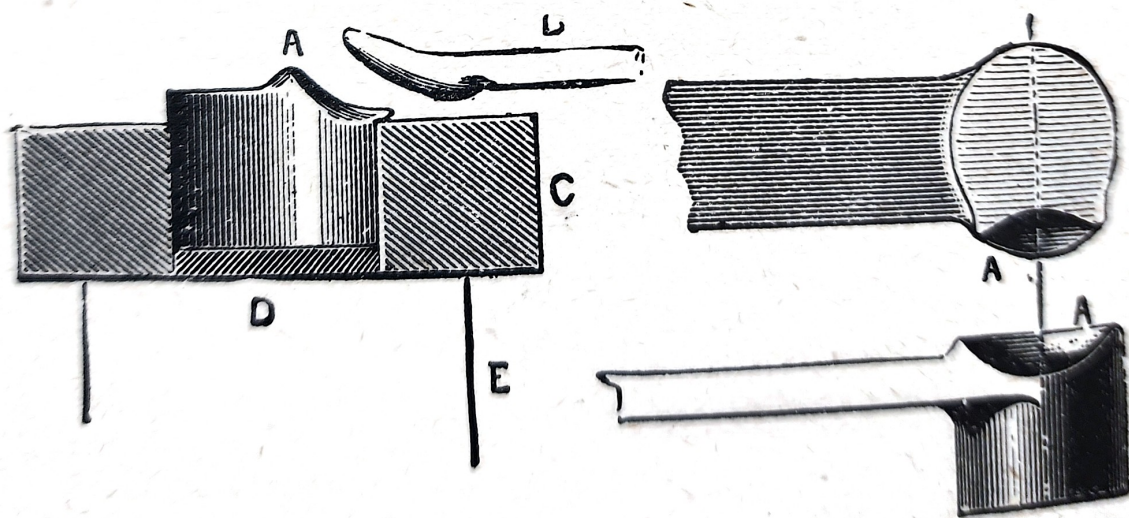


Fig. 142.—Welding on Arm.

Often the arms of bossed levers stand at an angle with each other, and also are not in the same plane, and then the methods previously described are not

applicable. Fig. 141 shows a portion of a lever, with arms placed on opposite sides of the boss at right angles to each other. There are two ways in which these levers may be attached to the boss. One by "dabbing on"—that is, the arm A, with a portion of the boss, is welded flat upon the main portion of the boss B, along the plane α , the surfaces being first hatched over with the corner of a set; by the other way (Fig. 142), one side of the boss, if fullered, as at

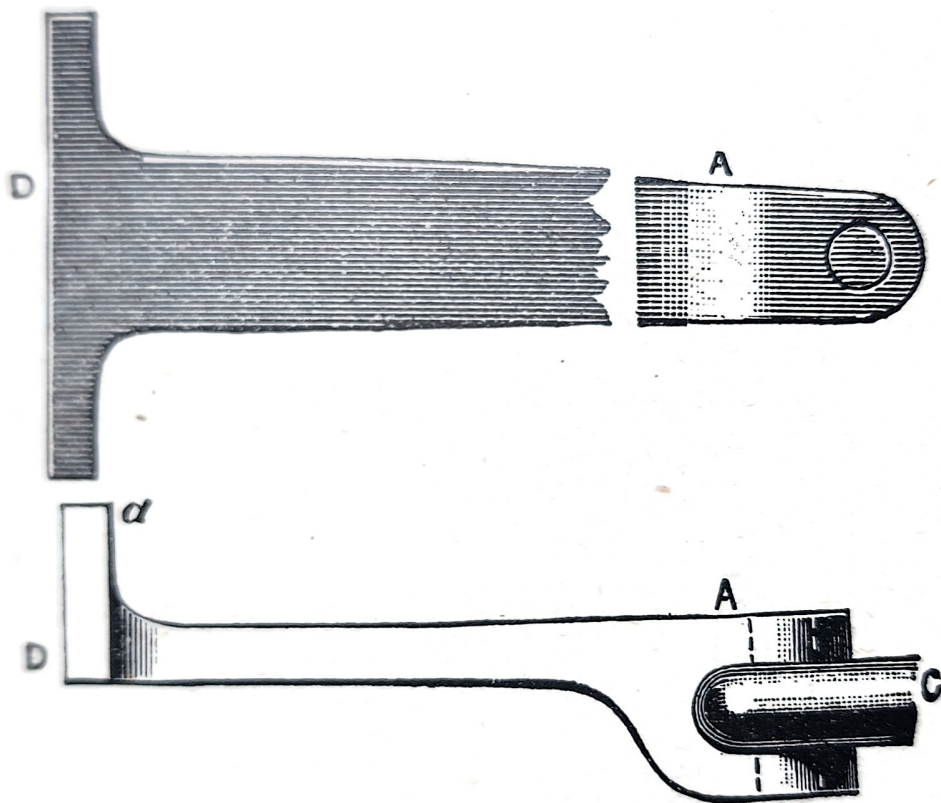


Fig. 143.—Eccentric Rod.

A, with a round-faced fuller, the end of the lever arm B is upset, and the two welded together. This is a very common method of welding. The fuller not only indents the boss, but, by means of blows delivered diagonally, is made to throw up the metal all around in a ridge, thus giving some extra metal for finishing off. In Fig. 142, c is a die-block, in which the boss is held while the arm is being welded; d is a thickness piece, or washer; and e is the anvil. If no

die-block is available, the boss will be held with open-mouthed tongs of globular form.

Eccentric and valve rods afford some typical examples of engine forgings. The eccentric rod (Fig. 143) is usually made in two pieces, and welded at about the center; or, if rather long, the ends are welded to a central plain bar.

The extreme dimensions of the end A represent roughly the original size of the bar, from which the shank B is drawn down. From that original bar there is swaged down a length sufficient for welding. The large end is cut off to the precise length required with the knife tool, or with the curved knife if the steam hammer is used, or with a hot set if power is not available. Then it is necessary to cut off upon the anvil any sharp corners with a cutting-off tool, giving the appearance of Fig. 144, and swage the end

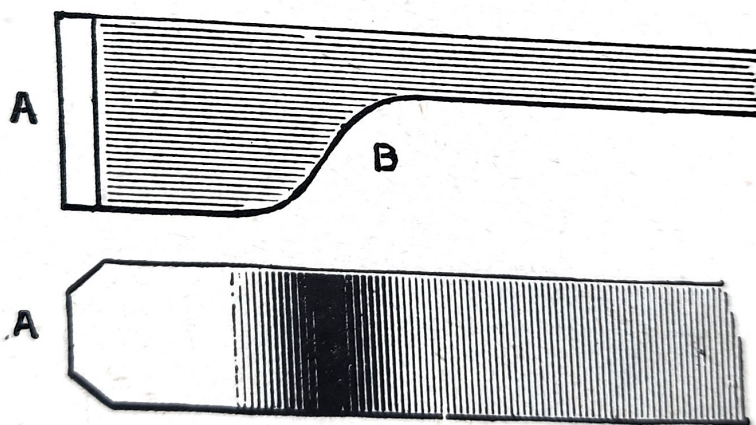


Fig. 144.—Forked End Roughed Out.

A, rounding with a hollow swage, letting the shoulder B lay against the beak of the anvil, and finally, to finish in a die-block (Fig. 145). Of course, the die-block is used for finishing only when the quantity of forgings required is sufficient to pay for its cost.

The body A of the block is of cast iron, and a wrought iron ring B is shrunk on. The recess C, it will be seen, corresponds with the outline of the end A in Fig. 143.

Another way to forge the forked end is to take a bar about half the thickness of the forked end, and double the iron over, and weld a length that will extend rather farther than the termination of the radius.

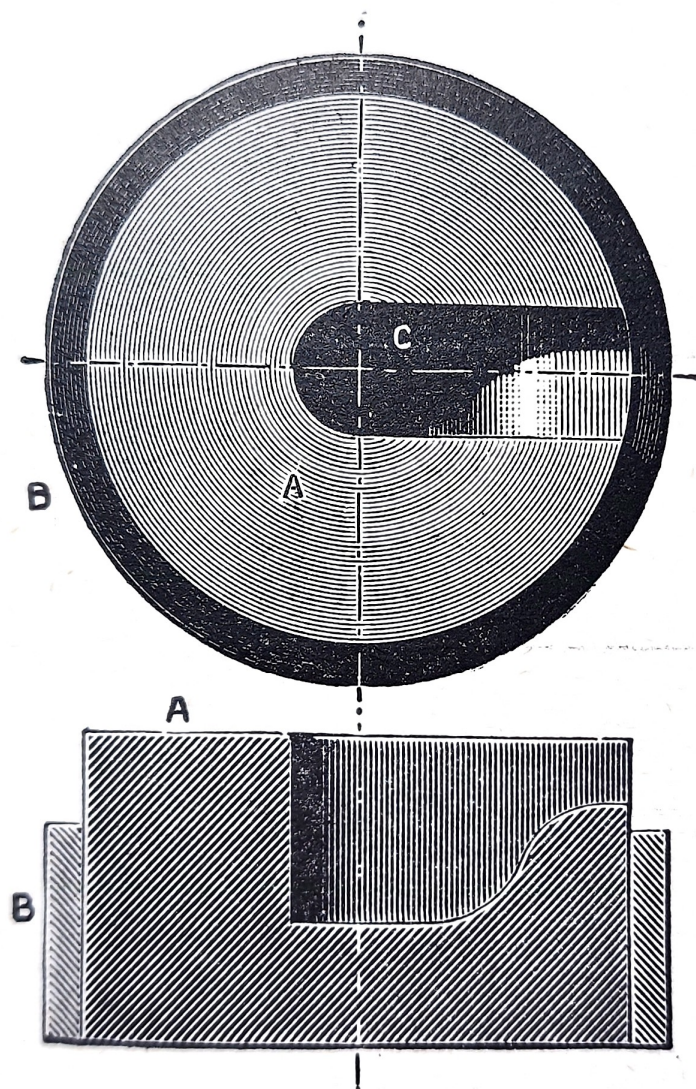


Fig. 145.—Die Block.

In both of these methods the gap may be cut out roughly by the smith or left to be machined out. The general methods of forming forked ends have already been described, and now it is only necessary to show by a sketch how forked ends, whose gaps are formed by forging, and not by machinery, are shaped. After

the metal has been cut out from the gap and roughly brought to form, a filler, shown shaded at c, Fig. 143, is inserted, and while this remains in, the outside of the forked end is finished with flatter and hollow swage. The filler usually has a square shank to fit the square hole in the anvil.

The end *d* in Fig. 143 is made by one of three methods. Either the shank *B* is fullered down from a bar of the original section of the end *d*; or the shank *A* (Fig. 146) is welded to a piece of flat bar *B*, of the

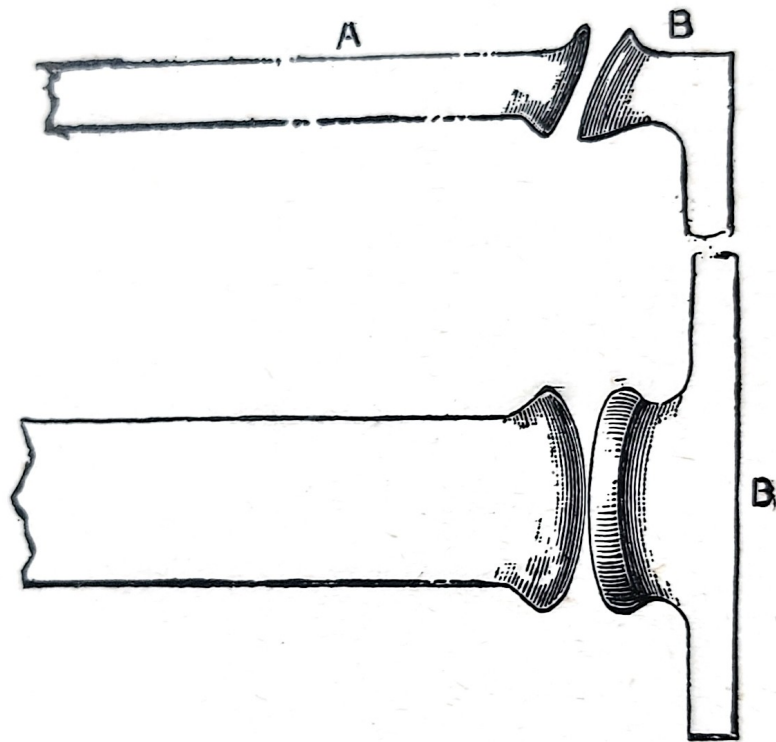


Fig. 146.—Welding Flat End of Eccentric Rod.

dimensions of the end *d* in Fig. 143; or the end of a bar is divided and opened out. The first method is not correct because the iron fibers are short, but it is often adopted, as there is not very much stress on the flat end when bolted up to the eccentric straps, and the hammering it receives at the welding heat helps to consolidate the metal.

The second method has the advantage of preserving the best arrangement of the fibers. In it, the flat

piece B (Fig. 146) is fullered and upset with a round-faced fuller, and the end A, similarly fullered, is welded to it. In either case, to permit of finishing off, the iron selected is a trifle larger in section than

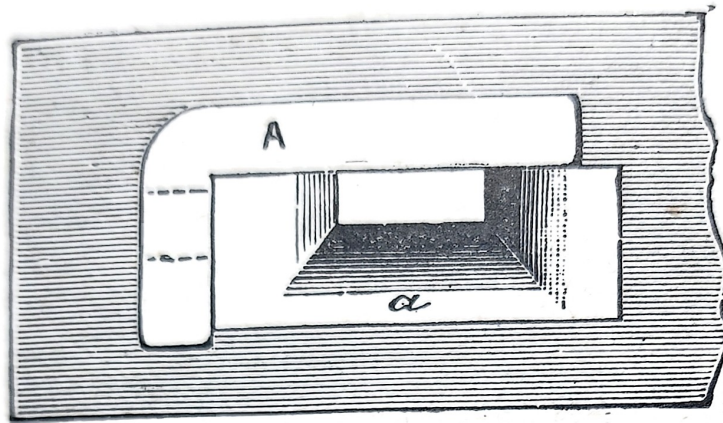


Fig. 147.—Anvil Stop.

the finished section. Where the shank is drawn down from the solid, a good deal of finish on face *a* (Fig. 143) has to be done with the flatter, the rod being held vertically with the face *b* upon the anvil face. To prevent the rebounding backwards of the forging, in consequence of the edge of the flatter striking the

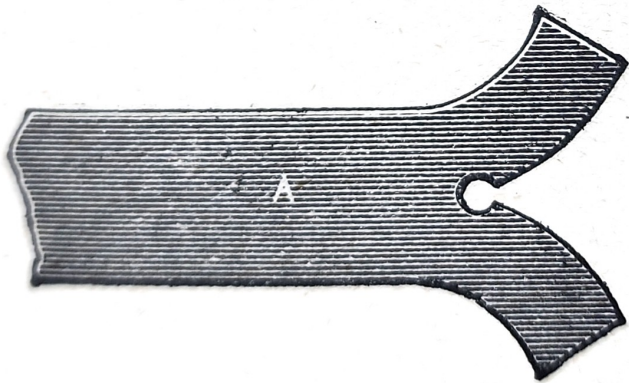


Fig. 148.—Opening Out End of Bar.

shank, a bent bar of iron (Fig. 147, A) is fitted with a shank into the hole on the anvil face. The flattening of the inner face *a* of course has a tendency to spread the edges and bulge them in some places, and this is corrected with blows on those edges from the hammer and from the flatter.

The third method of forming the flat end is by forking the end of a stout bar in the fashion shown in Fig. 148, and opening the ends outwards. Continuity of fiber is thus preserved. The end A is fullered down thinner, and drawn out, and then cut off

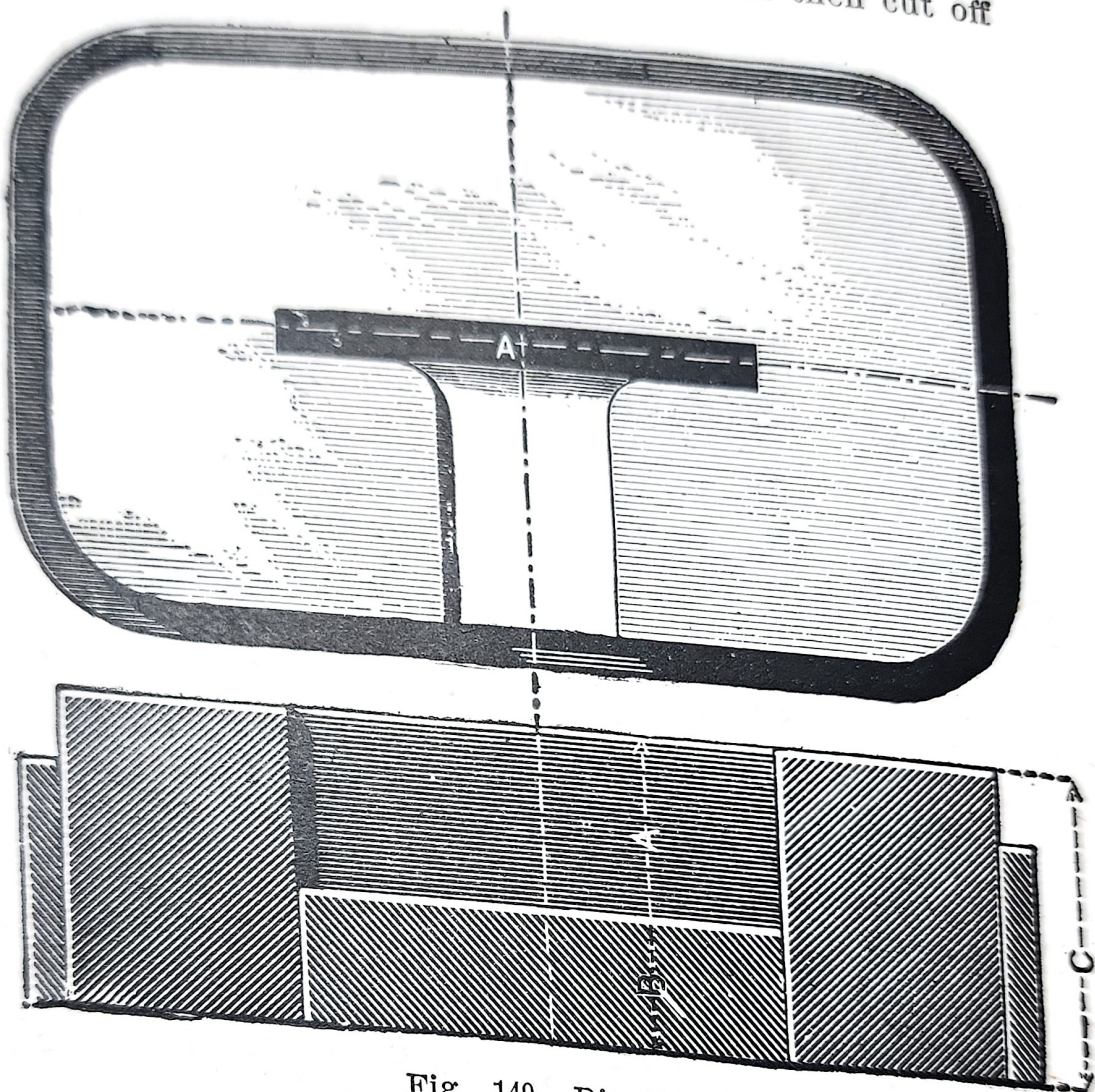


Fig. 149.—Die Block.

the main bar, whose length may serve as a porter, and scarfed for welding to the stem.

When these rods are made in quantities, the final finish is imparted in a cast-iron die of the form shown in Fig. 149, in which A is the recess that gives the flat end its perfect finish, and B a flat piece of steel, whose depth makes up the precise difference between

the depth c and of the flat end λ , and by means of which the T-end is driven out of the die immediately after it is moved off the anvil block of the steam hammer. The block being turned upside down, a blow or two on the piece B drives the finished T-piece out from the die.

When the fins formed at the edges are being cut off with the set, the forging is placed upon a piece of sheet iron, bent over at the ends to clip the edges of the anvil. This sheet of iron prevents the cutting edges of the set from becoming dulled by contact with the hard steel face of the anvil.

Bolts and nuts are bought more cheaply than they can be forged in small quantities, and they are consequently seldom made in smiths' shops. But a de-



Fig. 150.—Ring for Bolt Head.

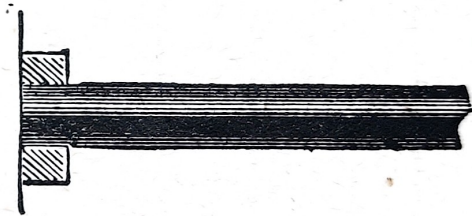


Fig. 151.—Rod driven into Ring.

scription of their manufacture is not superfluous, because in it are illustrated several facts that find useful application in other classes of work.

In making bolts there is the choice of three methods. In one, a bar is selected of about the size of the bolt head across the angles, and the stem is drawn down, first roughly by the hammer, and then between swages.

Another method is to take a bar of the diameter of the bolt and upset a mass of metal to form the head. Neither of these methods, however, is often adopted.

The usual method is to bend round and weld a ring of metal upon a bar, whose diameter equals that of the bolt. The details are as follows:—The heads are prepared as rings (Fig. 150) cut off from a rectangu-

lar bar of iron, and bent round upon the anvil beak or upon a mandrel, but not welded as yet. For the shanks, suitable lengths of round rod are cut off. To economize time, as many rings and lengths of rod are prepared as there are bolts wanted, and then the welding begins. First the end of a rod, made red hot, is driven through its ring (Fig. 151), which lies upon the anvil; the rod is next brought into a horizontal position, and the ring closed tightly upon it by two or three smart blows of the hammer, and also the end of the rod is slightly burred over with the hammer (Fig. 152) to keep the ring from slipping. That

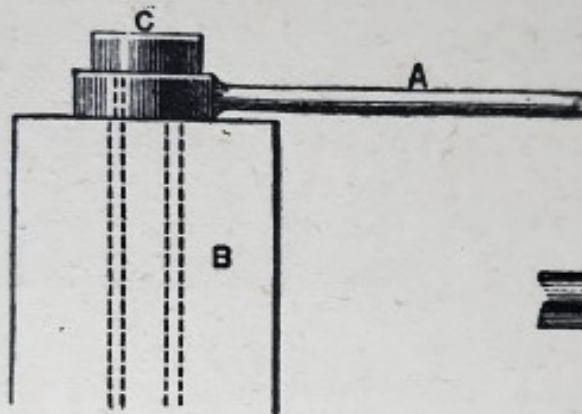


Fig. 153.—Bolt Header and Block.

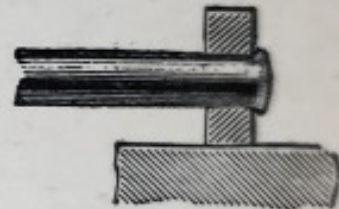


Fig. 152.—Rod burred in.

end is then put into the fire and raised to a welding heat, and sand is sprinkled over it just before withdrawal from the fire. The head is laid in a hexagonal bottom tool (Fig. 54, p. 32), and about half a dozen blows given to it, altering the position of the head after each blow. It is then put into a bolt header A (Fig. 153), resting on a cast iron heading block B, pierced with a central hole, and the top of the bolt head, c, is well beaten over with hammer and flatter. The bolt is then put back in the hexagonal bottom tool (Fig. 54, p. 32) and once more hammered on each separate face; then back in the bolt header, and struck twice or thrice with a flatter, and then finished with a cup tool, which gives the round-

ing at the edges. Finally, it is put back in the hexagonal swage, and a last blow given with the flatter on each face. All this is done at a single heat, and, when finished (Fig. 154), the bolt head, unless very small, is still at a good red heat. A description of an appliance used in rounding bolt heads commences on p. 12.

Many bolts, such as those used for glands and for some forms of plummer blocks, are furnished with collars. These are usually welded on as rings, and finished in a die or swage of the form in Fig. 49, p. 31.

To make nuts in small quantities, take a flat iron



Fig. 154.—Finished Bolt Head.

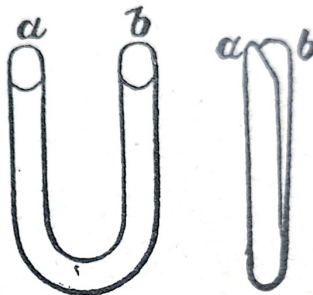


Fig. 155.—Rod Bent to Form Chain Link.

bar of a thickness and width the same as the nuts, and mark off and nick their lengths with a cold chisel. Center-pop the middle of each space. Heat the bar and over a bolster punch all the holes through in succession. Then cut off each nut on the anvil chisel, and finish on a mandrel.

The manufacture of chains is quite a distinct branch, but a smith is often called to mend a broken chain. When a broken link is replaced it is usually made a trifle longer than the normal link, for convenience of formation. Also, when a link is added to one end of a chain for the purpose of connecting it to any attachment—as a crane hook, for example—the link is made slightly longer. Such an added link is termed a shutting link.

To weld a shutting link, the iron rod is first bent to

a U shape (Fig. 155), then two opposite faces, *a*, *b*, are drawn off diagonally with the hammer, and the link is bent round to bring these faces nearly close together (Fig. 156). The link is then put back into

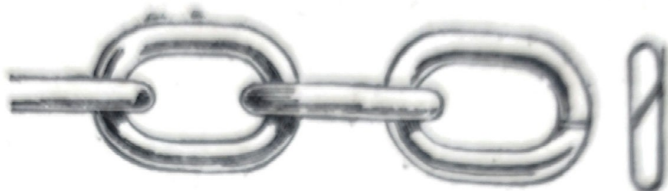


Fig. 156.—Chain Link.

the fire and brought to a welding heat, a little sand strewn upon the joint, which is closed smartly with the hammer, first on the flat upon the anvil, and then upon a tool (Fig. 157) fixed in the hole in the anvil.

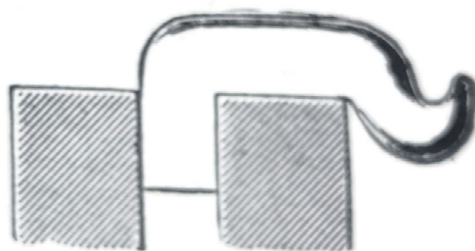


Fig. 157.—Link-forming Tool in Anvil.

To smooth and finish the link a hollow swage tool is worked around it.

Swivels are of common occurrence, and require some art in making. Fig. 158 shows a piece of iron



Fig. 158.—Bar Iron for Making Swivel.

bar, the cross section of which should be rather greater than that of the boss of the swivel, because then neither welding on nor upsetting is necessary. A hole is first punched at *a*, corresponding with the

eye of the swivel; then a moulding tool (Fig. 159) is laid across the red-hot bar, roughly concentric with the punched hole, *a*, and struck a few blows with the

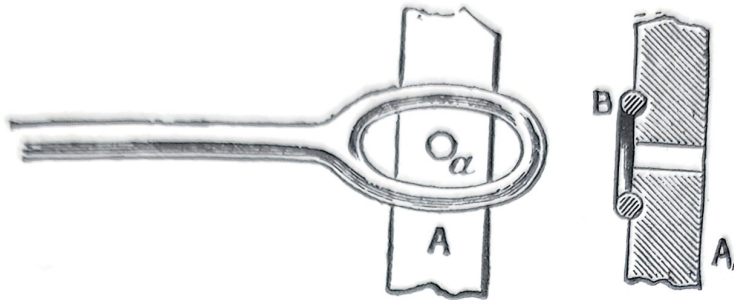


Fig. 159.—Moulding Tool for Swivel.

steam hammer, leaving the impressions *b, b* (Fig. 158).

In the absence of a steam hammer, a fullering tool would answer the same purpose as the moulding tool,



Fig. 160.—Boss of Swivel.

but it would take longer time. The moulding tool not only fullers, but imparts the desired curved form to the incipient boss. After fullering, the bar is cut off at *c* (Fig. 158), and the portions *d, d*, are drawn

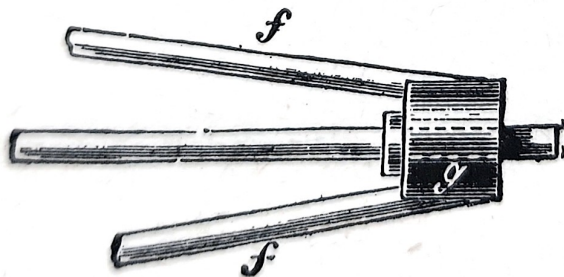


Fig. 161.—Mandrel in Swivel.

down to a sectional area a trifle larger than that of the arched portions of the swivel. At the same time the boss portion is shaped out of the lump *e* until the

forging has the appearance of Fig. 160. Then a mandrel (Fig. 161) is passed through the punched hole, *a* and the drawn-down ends are hammered over as at *f, f*. At the same time the forging, while on the mandrel, is finished all over, except just where the



Fig. 162.—Arms of Swivel Upset for Welding.



Fig. 163.—Bolster Tool for Forging Swivel.

weld is to be made, the boss *g* and the arms *f, f*, with their merging curves, all being gone over in detail with the hollow tools and fullers. The extreme ends of the arms *f, f*, are also scarfed and slightly upset, and the forging then has the appearance of Fig. 162. To afford support to the swivel during the welding,



Fig. 164.—Finished Swivel.

the beak of the anvil is utilized, or a special bolster like tool (Fig. 163) is fitted into the hole in the anvil. The face of this tool is shaped roughly to the curve of the swivel, and lends itself readily to the work of welding and finishing with hollow tools, during which

the position of the swivel on its bolster is being continually shifted. The form of the finished swivel is shown at Fig. 164, the scarfed weld being at *h*.

Another way of forming such a swivel is shown in Fig. 165. A round rod, *A*, is divided and forked, as

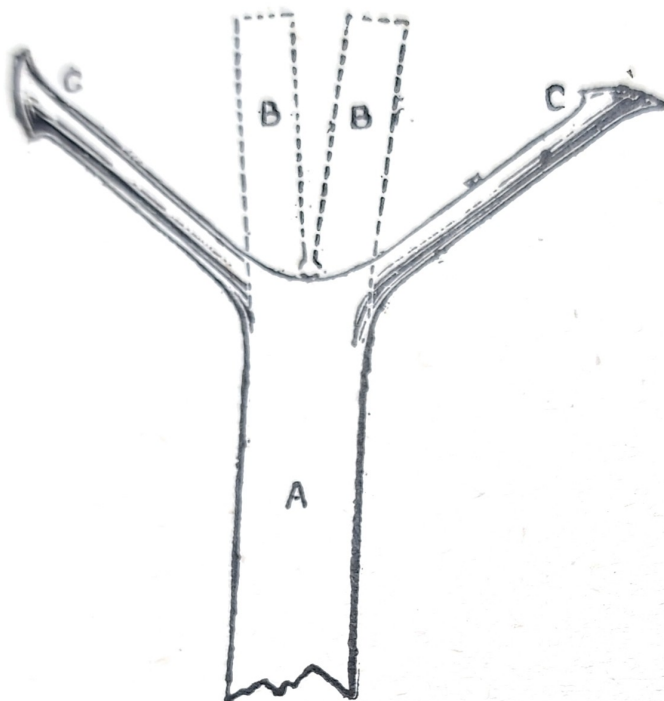


Fig. 165.—Swivel formed from Round Bar.

seen by the dotted lines, *B*, the divided ends still further opened out and drawn down and upset, as at *c, c*; after this, the process is similar to that previously explained.

CHAPTER VIII.

CRANKS, MODEL WORK, AND DIE FORGING.

The blacksmith is often called upon to forge cranks and crank axles. These appear in many different forms, so it is impossible to give fully detailed accounts of the methods employed in the construction of all of them. One or two cranks of the more general kind will, therefore, be noticed.

Suppose a common bent or dip crank of round section (Fig. 166) has to be made without assistance

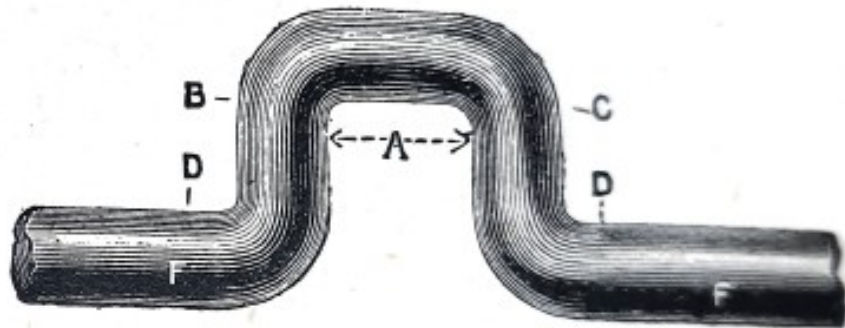


Fig. 166.—Bent Crank.

from a die-block. It would not do simply to bend a round bar to the cranked form, because at the corners where the bending takes place the area would be reduced by the stretching. Bad iron is of no use for a bent crank, for the process of upsetting and bending will open out the fibers; fagoted iron is often used.

A crank of this kind (Fig. 166) may have one, two, or three throws, and the axles extending at each end may be long or short. The cranks may be forged separately, and apart from the axles, and afterwards welded together, or all may be forged from one bar, as is most convenient.

It is supposed that the crank has only one dip; but to a certain extent it is applicable to cranks with two or three dips, the twisting of the dips to relative angles with each other excepted.

Before bending the dips, there will be three upsettings of the iron: one along the length, A, that is to form the future crank pin, and the bendings, reaching from B to C in Fig. 166, where the pin merges into the webs or arms, and two others where the webs are to merge into the axle, or from B to D, and C to D (Fig. 166). These upsettings are done before the bar is bent.

The bendings at B and C will be done either at one or two heats. If the pin is short, one heat will suffice, but if long, two will be necessary. Here the swage block, or the levelling block pierced with numerous holes, is of use; a couple of pins inserted into holes in either block, form suitable supports in pulling the axles round and preserve the true plane of the dip. If neither swage block nor levelling block is available, a pin placed in the anvil hole must answer the same purpose, but it will not be suitable for heavy work.

It is necessary to check the width, A (Fig. 166), before bending the other corners. Upsetting must be resorted to if too great, and drawing down if not enough.

The bending of the corners D, E, can be done around suitable pins, the axles F, F, affording good leverage. After this the crank webs from B to D, and from C to E, must be set parallel, and the axles F, F, set for alignment lengthways, and be brought into the same plane with the webs and pin.

In cranks of this type, it is desirable and usual to have rather an excess of metal at the corners, especially when they are to be finished bright. Such cranks, when made in quantities, are usually bent over a block, or they are stamped.

A bending block is shown in plan and elevation by Fig. 167. A section on A, B, is shown by Fig. 169,

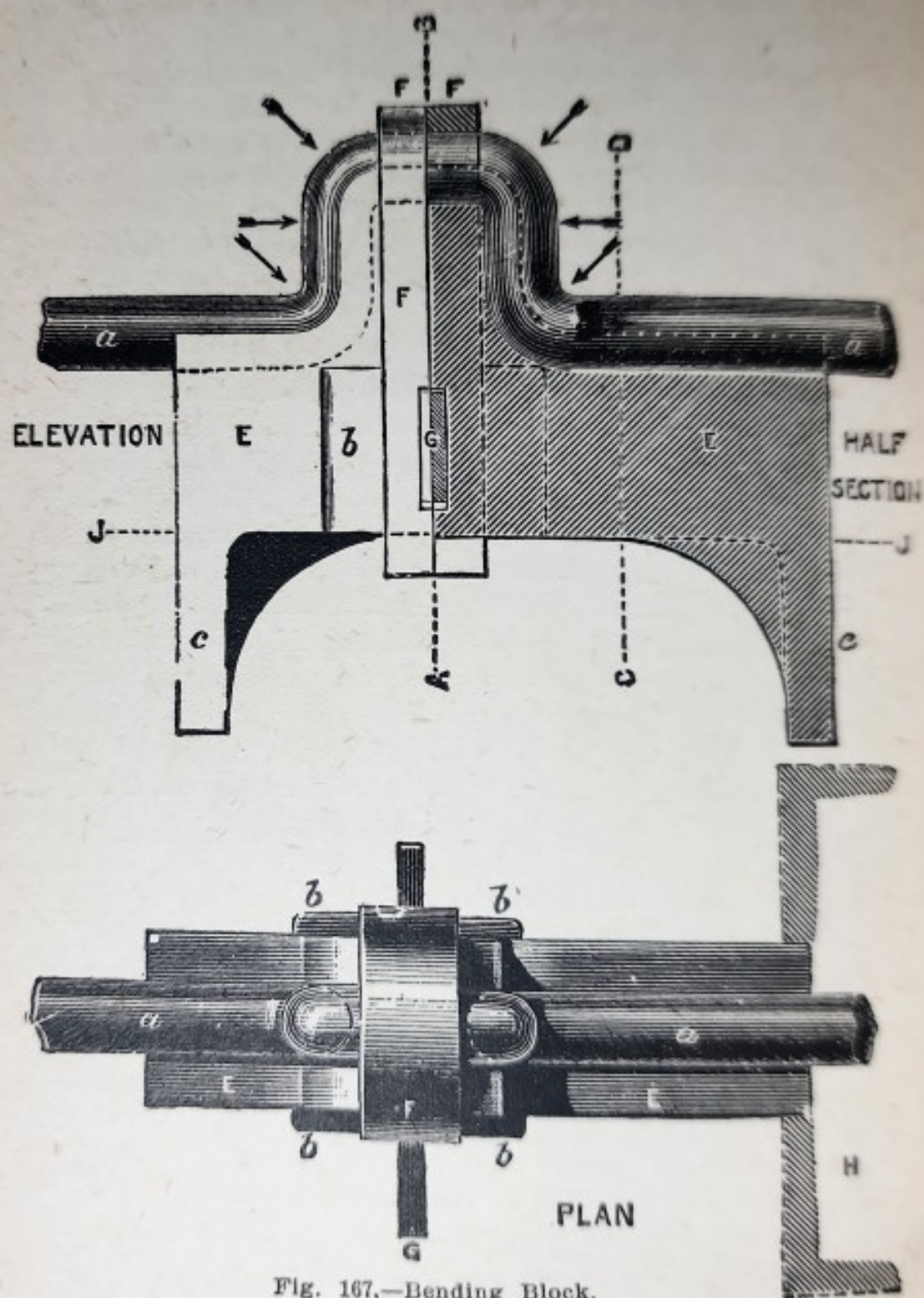


Fig. 167.—Bending Block.

and another on c, d, by Fig. 168. The block is a casting, E, sufficiently heavy to resist the hammer blows necessary for making the bends of the crank. Its width is therefore considerably greater than the diameter of the crank, and ample depth is given. The length is sufficient to permit of true alignment of the axle being made, though not necessarily so great as that of the crank axle. The distances from

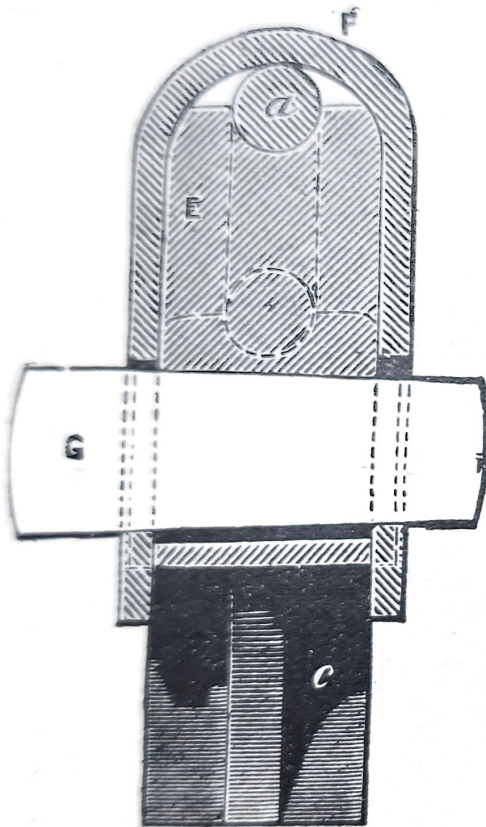


Fig. 168.—Section of Bending Block.

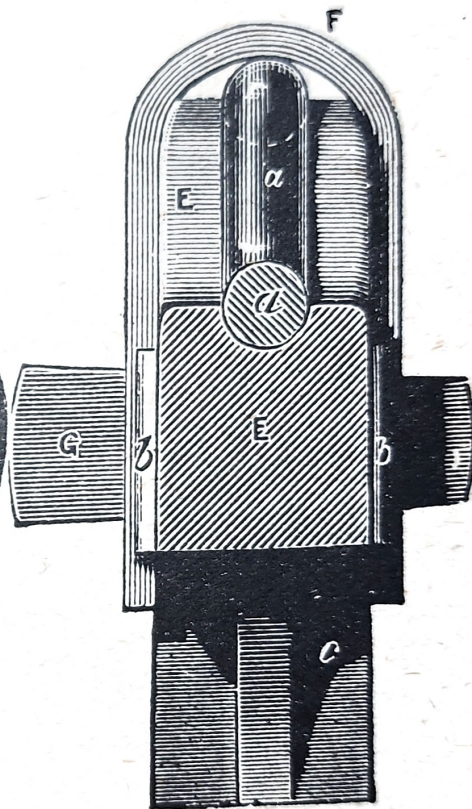


Fig. 169.—Section of Bending Block.

the center line A B to each end are made unequal to permit of the forging of cranks with two throws or three throws. For single dip cranks only the lengths would be equal. In Fig. 167 the right-hand end is made sufficiently long to afford a good bedding for the axle *a*, but the left-hand end is made short, so that after one throw is forged it may lie beyond the left-hand end to permit of the bending of the second or the third throw upon the block.

In the formation of a crank by the aid of such a block, those sections where the bendings are to be made are thickened by upsetting as before described, and the webs are bent upon the levelling block or upon the swage block, and the axles bent at right angles with the webs approximately true, though not necessarily so carefully as though the crank were intended to be finished by this method. The advantage of the block now becomes apparent. The crank *a*, heated nearly to a welding heat, is dropped over the block *E*, embraced by the strap *F*, tightened by the cottar *c*, which being driven in rapidly holds it in place, and the webs and the axles are bedded down into the curved recess of the block, hammer, fuller, and hollow tools being quickly brought into requisition wherever wanted. Thus the crank is practically finished, only a little smoothing over being done after removal from the block, chiefly at the sides which cannot be got at while the crank lies on the block. The crank should be removed from the block soon, or it will become bound tight, owing to the shrinkage of the metal by cooling. For this reason the sides of the block should be tapered slightly, and for large cranks, when making the block, allowance for shrinkage in cooling should be given at the rate of about $\frac{1}{4}$ in. per foot.

In Fig. 167, *b, b*, are guide strips cast upon the sides of the block *E* for the strap *F*. If the strap is not sufficiently stout, a clamp or a rough gib may hold its bottom ends together. The two horns, *c, c*, are cast on for convenience. As the blows for the most part are delivered in the direction of the arrows, the block needs to be steadied endwise; therefore, in the example from which this is taken, a heavy cast-iron block is sunk into the ground, a little below the shop floor. It is grooved out at one end to take the parts *c, c*, which preserve the bending block steady under the hammer blows. The grooved end of this casting

is shown dotted at H, Fig. 167; c, c, are below the ground—J J being the level of the floor.

If a second or third dip has to be forged, the truth of the first one is preserved by inserting in the dip a packing block B, Fig. 170, which gives an elevation

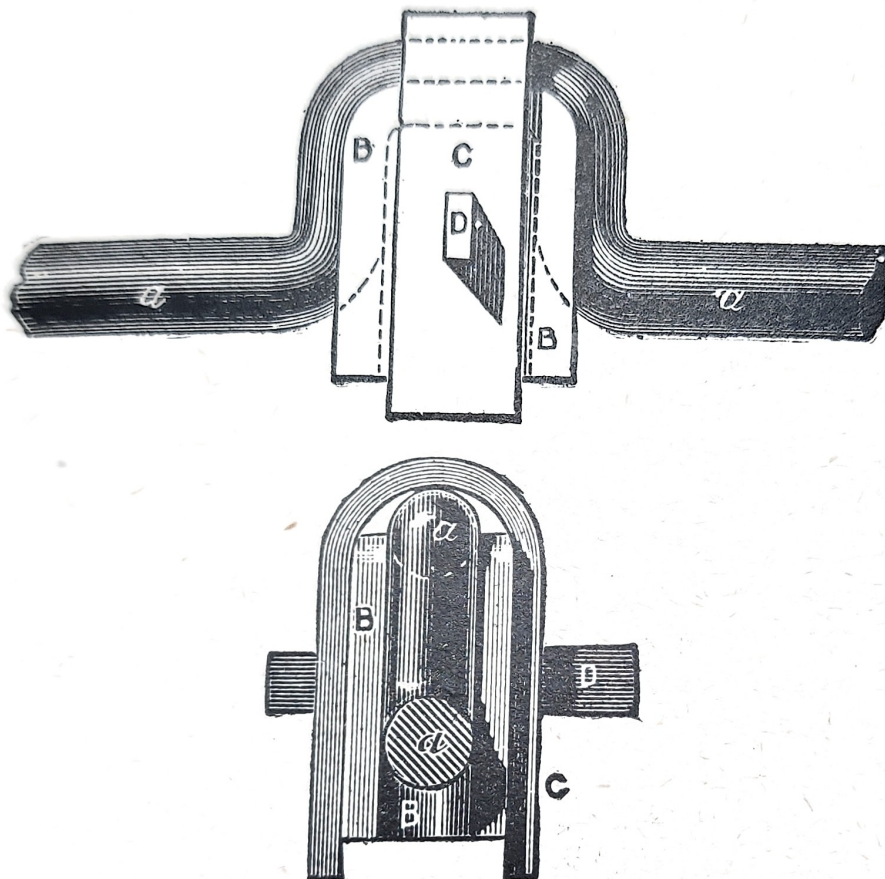


Fig. 170.—Filling-in Block.

and side view. This is a cast-iron piece hollowed semicircularly to fit the webs, and secured in place with a strap, c, and cottar, d. This is retained in place until the remaining dip or dips are bent. Fig. 171 shows a form of crank axle that is well adapted for forging into the strongest form possible, the fiber running round the bent portions. In some other forms the same advantageous disposition of metal is not secured.

Formerly it was quite common to see the largest crank axles of the general form shown in Fig. 172

built up by preparing separately the pin A, the webs B, and the axles C, and welding them together. The webs were opened out at the one end to embrace the pin and at the other end to embrace the axle, and then all welded together. Now it is usual in very large cranks, on marine engines especially, to make

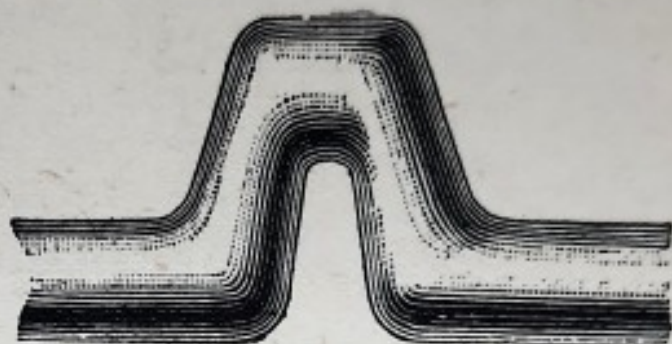


Fig. 171.—Crank roughly fullered into form.

and machine each of these parts separately and weld them together, shrinking the webs on to the pin. In small cranks of this type the forging is made solid and machined out. Briefly, the methods employed are as follows:—The simplest and the worst way is to cut the entire crank out of a slab. Better than

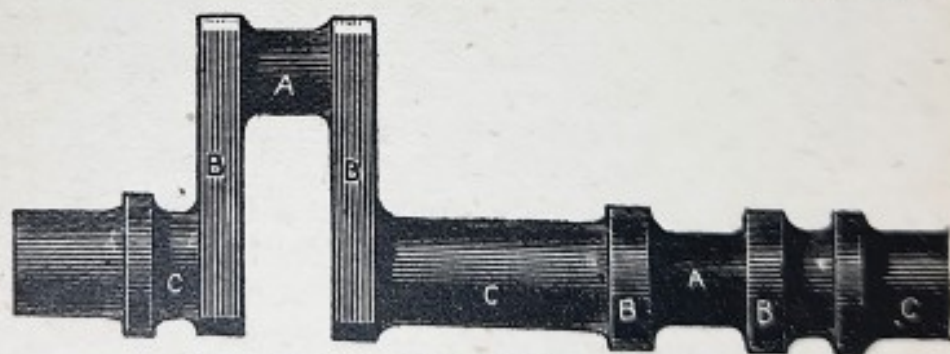


Fig. 172.—Locomotive Type of Crank.

this is the drawing down of the axles from a lump whose width is equal to the total width of the crank from the outer edge of the axle to the outer edge of the pin. Better still is the fullering out of a lump in such a way that an approximately curved disposition of the fibers is obtained (see Fig. 171), leaving,

however, a good deal of finishing and machining to be done afterwards.

Another way—not so good as the last, but more common—is to weld on one or several pieces, A, to one side of the bar, B, that is to form the axle (Fig. 173), leaving the gap to be slotted out or drilled out.

In cranks having two and three throws, the gaps stand at angles of 90° and 120° respectively. Cranks like Fig. 166 are usually forged with the dips at proper angles, but those like Fig. 174 are more often forged with the dips in one plane and twisted afterwards. When built, they are sometimes forged approximately at these angles. Sometimes each crank is prepared separately, and welded to suitable lengths

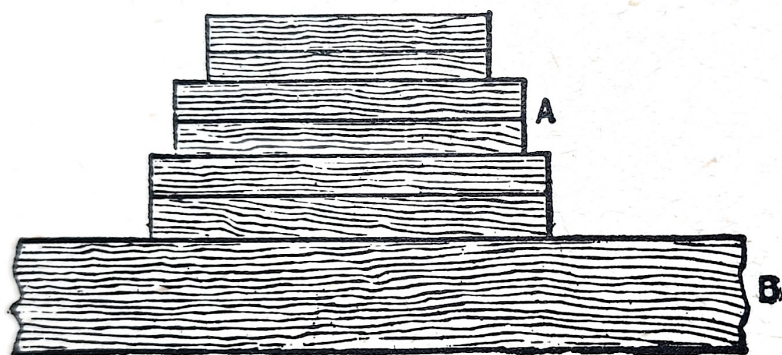


Fig. 173.—Piled Crank Lump.

of axle. When twisting is practiced it must be performed over as great a length of shaft as possible, in order to be gradual. Two or three heats may have to be given if the length is considerable, and a portion of the necessary twist imparted at each heat. One crank will have to be secured by some means, such as clamping down to the swage or levelling block or anvil, or holding under the steam hammer, or in the vice, while leverage is exerted at the other end. The leverage may be applied direct to the other crank, or to the axle itself, by means of clips. A few well-directed blows of the hammer will assist and serve to regulate the dead pull exerted upon the lever. If the cranks are welded to the axle, a long

and somewhat bulky scarf should be made, to give plenty of metal for subsequent consolidation and swaging down.

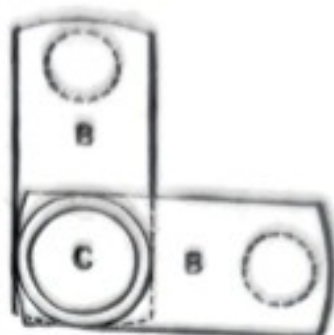


Fig. 174.—Locomotive Type of Crank.

The bosses for some large stationary engine-cranks when they are not upset, or the webs not swaged from the solid, are built up or bent round in various fashions. In one method the boss is formed by bending round a piece of bar *a*, and welding it to a straight portion *b* (Fig. 175). The bending is usu-

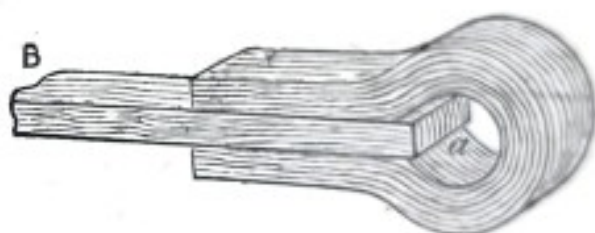


Fig. 175.—Crank Boss.

ally done by placing the bar across two supports, and fullering it down at the central portion. When the bar is thus partly bent, the curving is finished by closing the ends upon the anvil, till they just embrace the flat bar *B* in readiness for welding; more than one thickness of metal may be employed in the formation of the boss.

To finish such a boss, any excess of metal at the end, *a*, of the bar is cut off with a chisel, a mandrel is then inserted in the hole, and the outer curves finished with fullers.

Often, however, the loss is made simply by piling (Fig. 176). The pieces A, A, of any convenient thickness, are welded to the straight bar B, and afterwards are consolidated at a welding heat; a rudely curved form is imparted to them by means of fullering tools before final shaping with the set and finishing tools.

When the two bosses are prepared, the ends B, which have served as porters, are cut off, and the bosses united by means of a scarfed joint, thus forming a double-ended boss whose middle portion, or web, can be fullered and swaged down to the lesser section required.

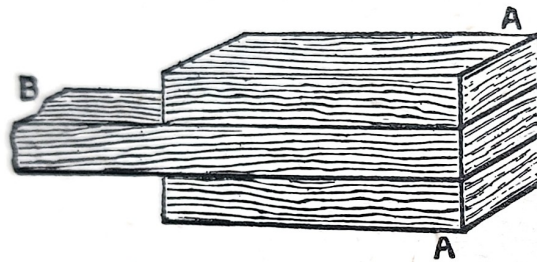


Fig. 176.—Lump for Crank Boss.

When extra strong and sound forgings are wanted, a solid new bar is not used, but a large number of selected pieces of any size and shape are welded together, the operation being known as piling or fagoting. The pieces are laid together in bundles of suitable sizes, bound round with iron to a porter or long bar of iron, and heated and welded and reduced under the steam hammer. For special work this process is repeated two or three times, the pile being drawn down, and then cut off into lengths that are re-piled, and reheated, and welded. The bars are not merely laid in parallel series, but are often made to cross one another at various angles, to secure greater strength. By this means, not only are forgings with the maximum of strength procurable, but all the odds and ends of metal cut off in the processes of forging are utilized.

Forgings for model work are necessarily expensive.

In the first place, in order to produce shapely and accurate forgings, much time must be spent upon them. In the second place, very few smiths care to undertake such work, because ordinary forging pays better, and because a man must execute very neat work to turn out perfect model forgings. Yet it is work that practiced amateurs, with time at their disposal, can succeed fairly well with, because patience more than high skill is wanted, and scarcely any of the really difficult operations of forgings are involved. Few special tools are required, most of the work being done with hammers and files. The cost of material is small, and the principal appliances are a small anvil and a vice.

In touching upon the differences between model and general work, it may be said generally that there is less of welding and more of drawing down done in forgings for model work than in those of heavy type. The difference in the dimensions of bossed-up ends or forked ends and their shanks or rods is so small relatively, that it is much easier to reduce the rods with the hammer than to weld the ends on. There is no great difficulty in welding small work, provided no time is lost in hammering the parts together immediately on removal from the fire.

For very light work, a small combined anvil and vice will probably be found serviceable. One advantage of a small anvil is that the beak is very useful to bend curves, and to form a suitable bedding when fullering down curved necks and shoulders for which the ordinary fullering tools are too large. The cross peens of the hammers are useful for this operation, and with different sizes various curvatures can be formed. Flatters are not used, all the battering and smoothing that is done being effected with the hand hammer.

Owing to the unsuitability of smiths' ordinary finishing tools for purposes of model work, the file

has to be used much more largely in this class of work than in ordinary forgings. When the forgings are cooling down to a black heat, a good deal of material can be removed with little effort, and a certain amount of finish imparted.

Again, in small forged work, many parts are left solid that in large work would be punched or fullered or cut out. The holes in bosses would seldom be punched, but wholly drilled. The forked ends of eccentric rods are left to be slotted or filed out.

In wrought iron used for model forgings, the same regard must be had to the direction of the grain as in larger forgings. But, in all respects steel is preferable as a material for model work to wrought iron. It is hard, rigid, and strong—important considerations—takes a better polish, and is more durable.

Die forging, or stamping, is adopted by the smith for repetition work. There are numerous parts in nearly all branches of smiths' work that are required precisely alike, and an enormous saving is effected by the use of dies. Such parts as flat links for chain, flanges for steam and exhaust pipes, some portions of valve gear, ornamental bosses, railing heads, pins, small levers, and similar articles more or less intricate, can be readily stamped with proper appliances.

Large dies are usually made of cast iron, and the smaller of steel. In large dies the required impressions are cast, and afterwards cleaned and smoothed a little with the file; in small dies they have to be cut out with drills, chisels, and files. In either case, sufficient metal must be put into the die to enable it to withstand the concussion of the blows. Cast dies are frequently bonded with a wrought-iron ring, in order to prevent their bursting. For this kind of work the sledge is of no use, generally the drop hammer, steam hammer, or hydraulic press being used. In little shops unprovided with power, the Oliver often serves.

In the plainest work a single die will often suffice, and the formation of the die must vary with the shapes of the forgings. But if the top of a forging is not flat, then two dies must be used, the upper portion being cut to the requisite outline. The top portion must also be attached to the lower in such a way that it will take its proper position in relation to the lower instantly, without any adjustment. This is usually effected by means of iron dowels, two or three dowels being driven tightly into the lower portion of the die, and standing upwards to fit loosely into corresponding holes drilled in the top portion of the die. The dowels are well tapered, and their ends rounded off so as to go more easily into the holes in the top portion of the die. The bottom dies are sometimes furnished with long handles, or they are lifted about with the hoop tongs, the top dies alone being furnished with handles. When holes have to be punched in the forgings, corresponding holes are usually drilled in top and bottom dies. The top holes are then parallel, and of the same size as the punch which is inserted in them; but the bottom ones are of the same size only where the lower face of the forging lies, being tapered downwards to allow the punched discs to fall through freely.

In many cases two sets of dies are requisite to produce an article; one set will form the sides, and another set the top and bottom. Of course, dies are expensive and, as a general rule, only pay when there are at least several dozens of an article required.

In stamped work, the amount of material required for any given forging must be gauged with accuracy. If there is an excess of metal, there will be thick fins spreading over the edges. If, on the other hand, the metal is short, then the forgings will not come up keen and clean, but will have edges more or less rounding and inaccurate.

CHAPTER IX.

HOME-MADE PORTABLE FORGES.

Illustrations and brief descriptions of some of the better known forges are given in Chapter I., but it is thought that some readers, instead of buying a forge



Fig. 177.—Home-made Portable Forge.

ready-made, may wish to construct one themselves. Such readers will be interested in the following par-

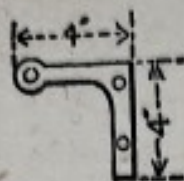


Fig. 180.—Bracket for Supporting Lever of Portable Forge.

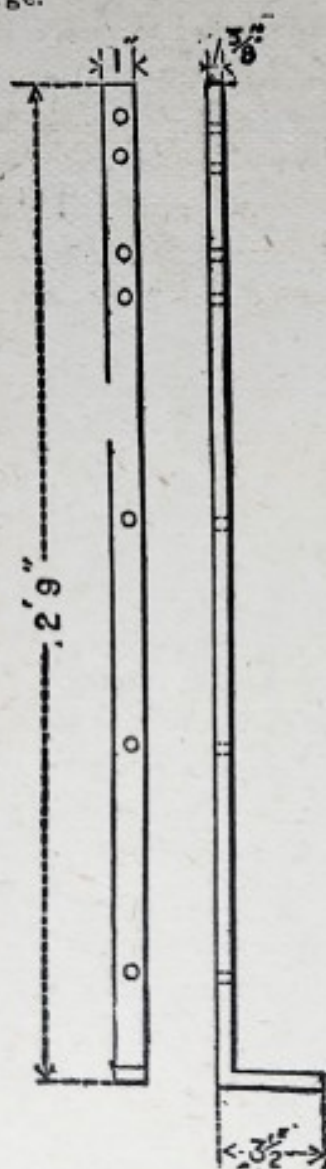


Fig. 178.—Legs of Portable Forge.



Fig. 179. — Pattern for Portable Forge Tray.

particulars of a portable forge which can be easily made by an iron-worker. The appliance (Fig. 177) consists of a wrought-iron frame, on the top of which is the tray, or hearth; and underneath is the bellows and blowing arrangement.

The whole of the framework is made of 1 in. by $\frac{3}{8}$ in. square iron bar, and is riveted together by $\frac{3}{8}$ in. by $\frac{7}{8}$ in. and $\frac{3}{8}$ in. by $1\frac{1}{4}$ in. iron rivets, the holes being bored to allow the rivets to fit in rather tight. The dimensions of the various parts of the framework are all in the illustrations.

The framework consists of four legs, A, A, A, A (Fig. 177), braced together by the cross-stays, B, B, two above and two below the bellows. The two stays above the bellows are not shown in the figure, being hidden by the tray, etc. They are of the same form and dimensions as the bottom pair, except at the center, where they cross each other, one of them being cranked down to allow the other to cross at its own level, and thus make a level bed for the hearth-tray to rest on. One of the legs is shown in front and side elevation in Fig. 178.

The various parts of the framework should first be forged and cut to dimensions given in drawings, and tried to make sure that they are all exact before marking out for drilling. The two cross-stays, B, B (Fig. 177), are riveted together where they cross in the center of the frame as shown. The ring, D (Fig. 177), is placed round the outside of frame at the points where the cross-stays are riveted to the legs, and the rivets pass through the ring, D, legs, A, A, A, A, and cross-stays, B, B, binding them all securely together.

The hearth consists of a flat, round plate of iron, sufficiently thick to withstand the heat; it is more serviceable, though a little more expensive, if made of thinner material and a circular fireclay brick bottom is placed on it. The hearth-plate rests on the

top pair of cross-stays, and is riveted to them by four rivets, two in each stay. The circular band, *i*, surrounding the hearth is cut out of 3-16 in. sheet iron to the shape shown at Fig. 179; the hole *A* is for the introduction of the tuyere, *j*, from the bellows. The

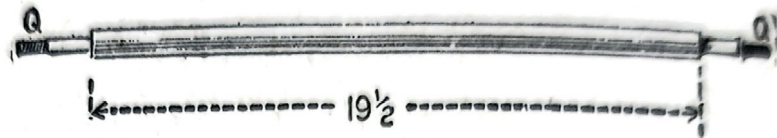


Fig. 181.—Spindle of Portable Forge.

band is riveted to the top of each leg by two rivets, as shown at *P*, *P* (Fig. 177), and is also riveted together at its two ends, as shown at *o*, by four rivets. The hearth-plate is cut to exactly fit inside the band, *i*, and to rest on the top pair of cross-stays.

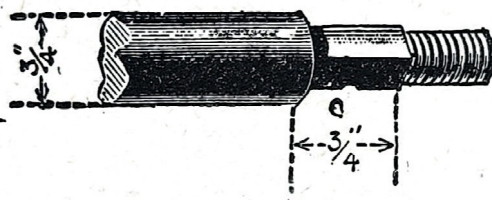


Fig. 182.—End of Spindle of Portable Forge.

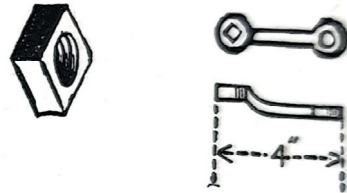


Fig. 183.—Crank on End of Spindle of Portable Forge.

The bellows work consists of a spindle of $\frac{3}{4}$ -in. round iron, working in two brackets, shown at *K* (Fig. 177), and in detail by Fig. 180. One of these brackets is riveted to each of two opposite legs, by two rivets in each as shown in Fig. 177. The spindle

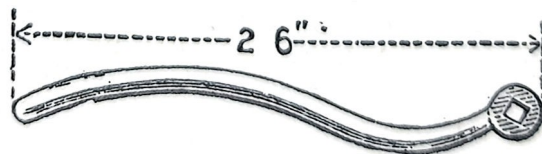


Fig. 184.—Lever on End of Spindle of Portable Forge.

is shown at *H* (Fig. 177), and also by Fig. 181, the ends, *q*, being squared (see Fig. 182) to fit the small cranks, *L*, and the long lever, *M* (Fig. 177). These

cranks are shown in plan and elevation in Fig. 183, and the long lever in Fig. 184. As will be seen from Fig. 182, the ends of the lever are squared and screwed. The length for the square part is $\frac{3}{4}$ in.

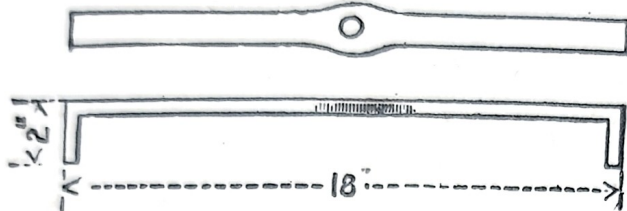


Fig. 185.—Guide-stay for Bellows of Portable Forge.

This is for the end carrying the long lever, as well as the crank; the other end, which carries only a crank, will have the squared part $\frac{1}{2}$ in. long.



Fig. 186.—Guide-pin for Portable Forge Bellows.

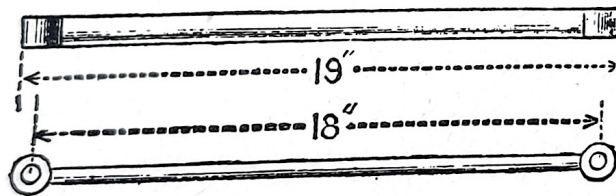


Fig. 187.—Bellows Links of Portable Forge.

The cross-stay, *c* (Fig. 177), acts as a guide to ensure the top chamber of the bellows rising and falling perpendicularly. It is secured to one pair of legs by rivets as the cross-stays are; it is made of 1 in. by $\frac{3}{4}$ in. iron bar, swelled out and has a hole in the center, as shown at Fig. 185, to allow the guide-rod, *f* (Fig. 177), to slide easily through. The upright $\frac{1}{2}$ -in. round guide-rod and square plate are shown in

Fig. 186. The plate is countersunk to receive four screws, which attach it to the top board of the bellows, the rod being riveted into the plate. The bellows, E (Fig. 177), is fastened to the frame by four

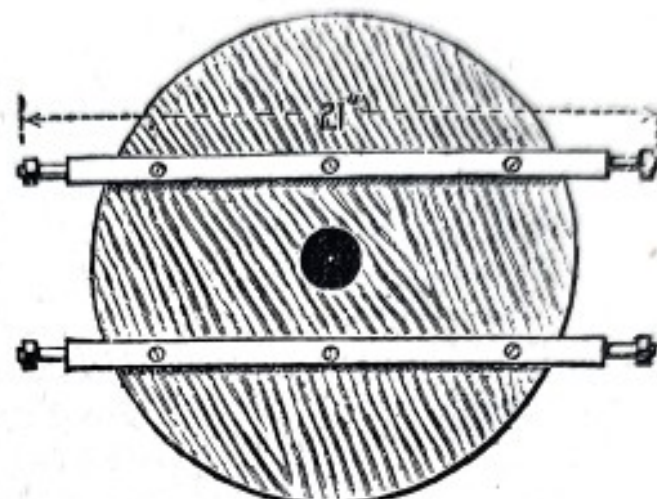


Fig. 188.—Under View of Portable Forge Bellows.

stout wood screws, one through each leg. Between the legs and the center board of bellows are placed four pieces of $\frac{1}{2}$ -in. iron pipe, each about 1 in. long; the four screws pass through the legs into these

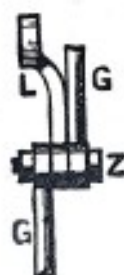


Fig. 189.—Link and Crank Connection of Portable Forge.

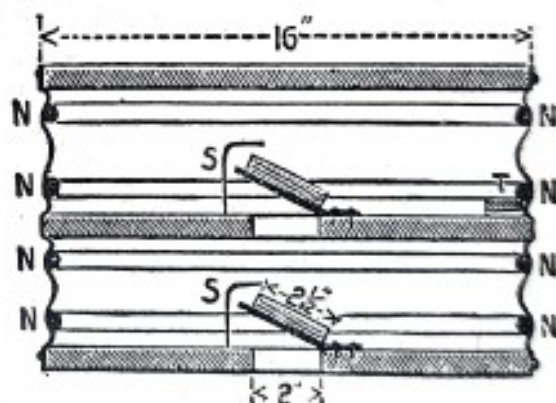


Fig. 190.—Section through Portable Forge Bellows.

pieces of pipe, and are driven home into the center-board of bellows, holding them quite securely.

The bottom chamber of the bellows is supported by four links, shown at *a, a, a, a* (Fig. 177). Each

end of these links is swelled out (see Fig. 187) at the bottom ends, and has a hole to fit on the round ends of two flat bars made of 1-in. by $\frac{3}{8}$ -in. iron bar, running across the bottom board of bellows (shown in Fig. 188), and at the top ends for the reception of the $\frac{3}{8}$ -in. bolts, which connect them to the short crank, *L* (Fig. 177). This arrangement is better seen at Fig. 189, *L* being the short crank, *g, g* the links, and *z* the $\frac{3}{8}$ -in. bolt and nut. The flat bars just men-

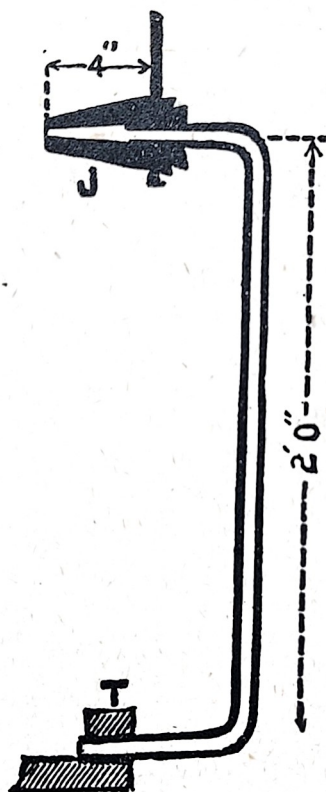


Fig. 191.—Nozzle and Bellows Connection of Portable Forge.

tioned are drawn out to a round section at the ends, and screwed for nuts, which keep the links in their place. They are fastened to the bottom board of the bellows by three screws in each passing through holes drilled and countersunk to receive them.

The bellows is composed of three circular boards of inch stuff, $14\frac{1}{2}$ in. in diameter. The middle and bottom boards are each provided with a valve, opening upwards. These are made by drilling a hole, 2 in.

in diameter, in the center of each board. Over each of these holes is placed a flat, circular piece of leather nailed to the board at one side which forms a hinge, but otherwise free to move up and down for the passage of the air. A piece of wood is glued on the top of the leathers, to ensure that they shall drop flat and close the valve when the air is within.

A wire stop, *s* (Fig. 190), is driven into the board, to prevent the wood valves turning completely over, in which case they would not again close when re-

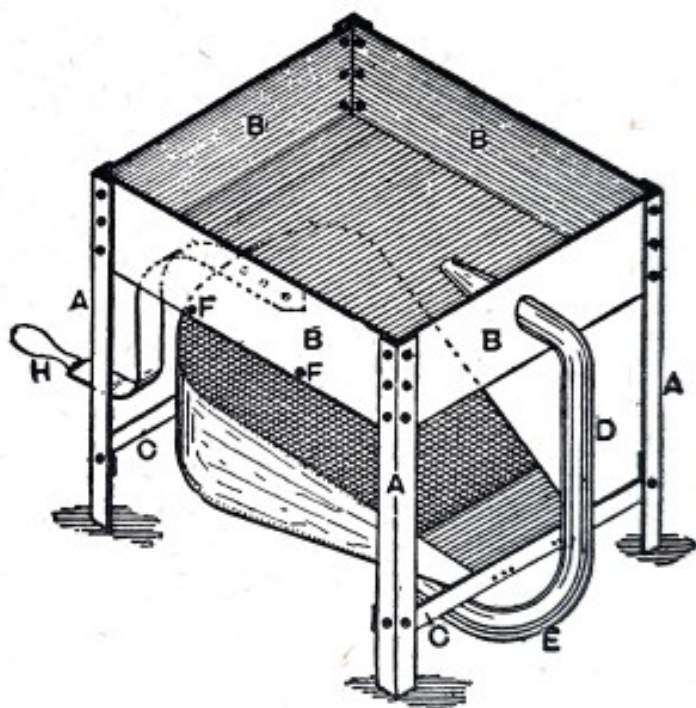


Fig. 192.—Small Portable Forge.

quired. The middle board has a block of wood fastened to it, for the reception of the screwed end of the pipe conveying the blast from the bellows to the hearth.

The three boards are fastened together by a piece of leather 14 in. wide, which goes all round them, and is securely nailed to their edges by 1-in. clout nails, placed in two rows, and as near together as possible. The leather of the bellows covering should be of good

quality, and may be obtained at any leather-seller's. It is scarcely likely that a piece will be obtained sufficiently large to make it entire, so it may have to be joined. A strip of leather, 1 in. in width, is placed round the edge of each board over the leather covering, and the clout nails are driven through this and the leather covering into the boards. Before fixing the leather on to the boards, two rings of $\frac{1}{4}$ -in. round iron bar, $14\frac{1}{2}$ in. diameter outside, are inserted in each chamber. These are to keep the leather stretched outward, and to ensure it forming even creases when opening and closing. The two ends of the circular band of leather covering the bellows should be joined with copper rivets and washers, such as are used in leather hose, put as near together as possible.

The pipe leading the air blast from the bellows to the hearth is of $\frac{3}{4}$ -in. iron tube, and is shown in section, with its fittings, by Fig. 191. At the bottom it is screwed into the wood block T, and at the top into the tuyere, J, through the iron band encircling the hearth, with a back nut and washer to keep it secure. The tuyere should be of thick wrought iron, and tapped to receive the end of the $\frac{3}{4}$ -in. tube as shown. The forge is now complete, and it only remains to regulate the flow of air by putting weights on the top board of bellows. Weights should also be suspended from the bottom board sufficient to draw the lever up when pressed down.

Of course, the dimensions of the forge may be varied, and the material can even be made lighter; but, owing to the knocking about such a forge has to sustain, it will be best to keep as near as possible to the dimensions given.

Another portable forge (Fig. 192) is made of wrought iron, with the exception of the tuyere; this may be the hub of a plough or other wheel. The legs (A, Fig. 192) are of 1-in. angle iron 1 ft. 6 in.

long. The sides and end-plates are of $4\frac{1}{8}$ -in. by $\frac{1}{4}$ -in. fender plate, and are respectively 18 in. and 15 in. long. One of the end-plates is drilled through with a $1\frac{1}{4}$ -in. hole for the reception of the blast-pipe *b* (Fig. 192). *c, c* are the stays as set out in Fig. 193;

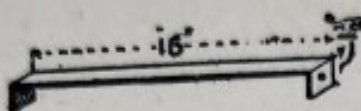


Fig. 193.—Stay of Portable Forge.

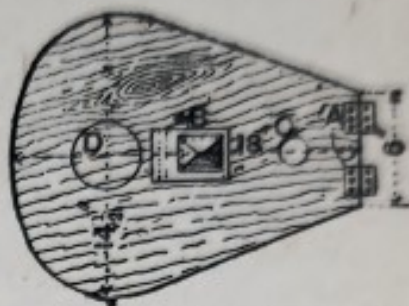


Fig. 194.—Plan of Portable Forge Bellows.

they strengthen the legs and support the bellows. The single-blast bellows, as shown in detail by Fig. 194, are made of two 1-in. pine boards, cut to the dimensions given, and hinged by cast butts at *A*; *B* is the valve which is required in one board only; *c* is the hole for the delivery-pipe; the bend with union shown at *E* (Fig. 192) and *D* (Fig. 194) indicates the

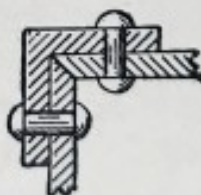


Fig. 195.—Joint of Corner of Hearth.

position of the bellows spiral spring. The bellows, which is made of basil leather, opens to $7\frac{1}{2}$ in. *H* (Fig. 192) may be either a handle or a step, or a combination of both. *F, F* (Fig. 192) show the rivets which hold a ledge inside to support the bottom of the forge. This bottom is of soft steel, 18 in. by 15 in. The delivery-pipe is threaded at *G* (Fig. 192) for 4 in., and a nut (not shown) on each side of the fender

plate holds it securely in its place. The bellows is secured by ordinary screws, which pass through the stays, but small bolts might be used with advantage. The whole thing is fixed together with round-headed rivets $\frac{1}{2}$ in. by 3-16 in.; the sides may be filed to a mitre joint, see Fig. 195.

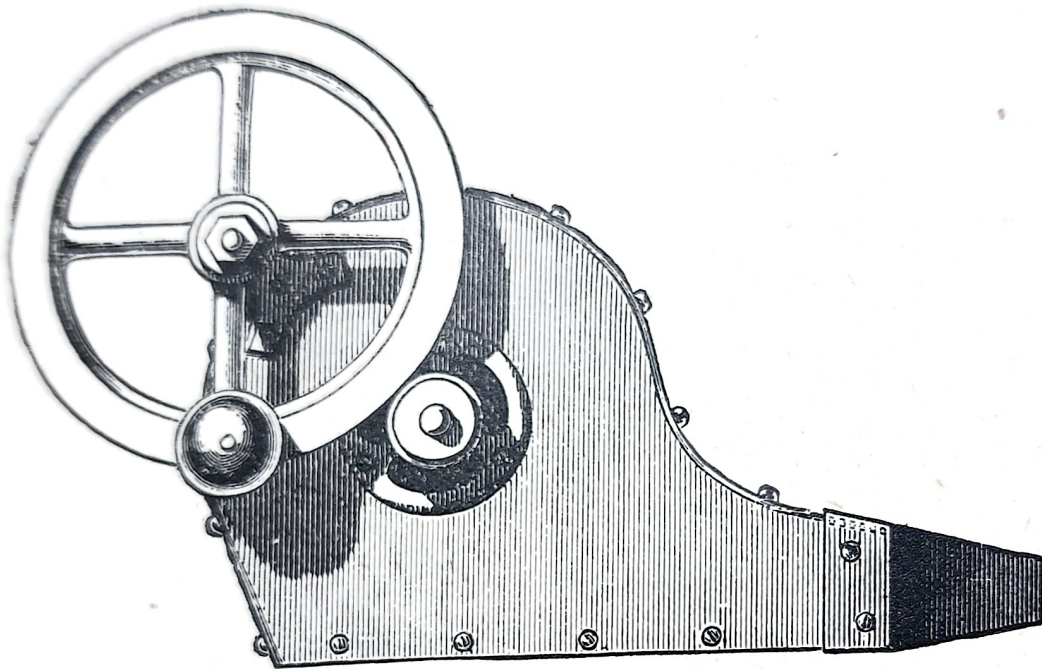


Fig. 196.—Side View of Continuous-blast Blow-bellows.

The construction of a continuous blast blow-bellows (see Figs. 196 and 197) will now be dealt with. These emit a continuous current of air instead of the intermittent current of the old-fashioned ones; instead of getting the draught from a 3-16-in. hole, or thereabouts, it is got through a hole $2\frac{1}{2}$ in. wide and $\frac{3}{4}$ in. deep, and these bellows cost only about half as much.

To commence the construction of the bellows, cut out the sides and the bottom, but do not screw them together. Make a spindle (as Fig. 198 and 199), drill two holes in each side, one at each end, as shown, and tap them and screw a piece of wire to fit; cut it

into pieces about 5-16 in. long, and screw a piece into each hole. Four pieces of tin, a little narrower than

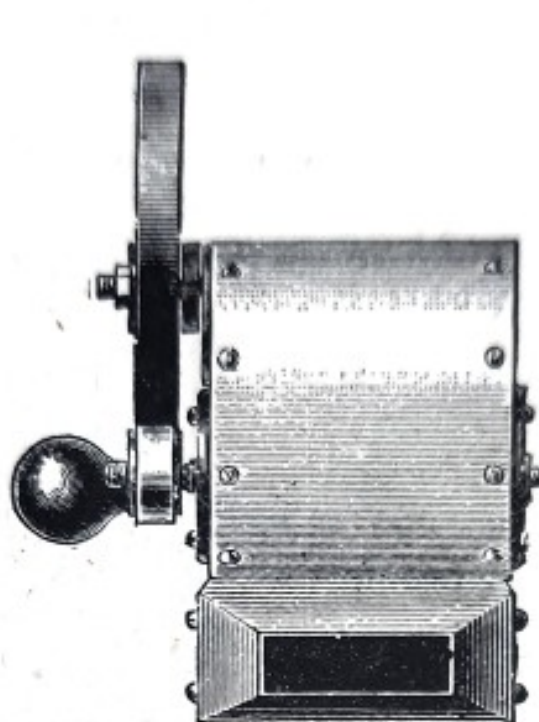


Fig. 197.—Front View of Continuous-blast Blow-bellows.



Fig. 198.—Spindle of Blow-bellows.

the bellows, have corresponding holes punched in them for the pieces of wire to slip through; put one

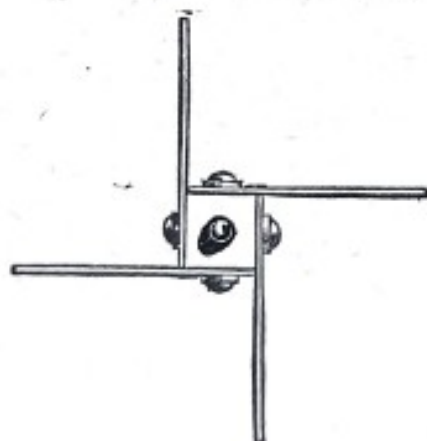


Fig. 199.—Side View of Blow-bellows Spindle.



Fig. 200.—Brass Bearing for Sides of Blow-bellows.

of them on, slip a washer over the wire, and then rivet it over. Treat all in the same way, and then

screw the brass bearings (Fig. 200) to the sides, fit in the iron spindle, and screw sides and bottom together, afterwards screwing the piece of metal over the top.



Fig. 201.—Brass Spindle for Blow-bellows Wheel.

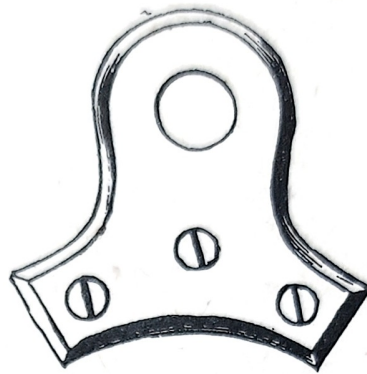


Fig. 202.—Plate for Fixing Wheel of Spindle.

The wheel will have to be bought. Fig. 201 is a sketch of spindle for it to run on. Turn this up, screw it at each end, fix it with a nut to the plate



Fig. 203.—Wood to Screw on Spindle of Blower.

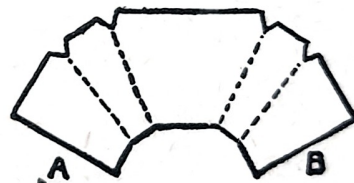


Fig. 204.—Pattern for Nozzle of Blower.

(Fig. 202), put on the wheel, and keep it there by a washer and another nut, then fit the knob on rather loosely. But before fixing the wheel, turn a bit of wood (Fig. 203) and over it put an indiarubber band, and screw this on to the projecting end of the iron spindle; fix the wheel against this tightly. In Fig. 204 is shown the shape of the nose-piece. When correctly cut out, bend this over at right angles at all the dotted lines, and it will fit on the end of the bellows. Either rivet or solder together the two edges, A and B, then drill it and screw it on. When this is all done, turn the handle rapidly; the fan inside will

then revolve at a good rate, and a strong draught will be obtained. Of course, the fan can have five or even six wings, but in such a case it is advisable to strengthen the wings by soldering pieces of wire between them, as in Fig. 205.



Fig. 205.—Side View of Blow-bellows Spindle and Fan.

Another improvement is to turn a small groove in the iron wheel, and fix it a little further away from the iron spindle; turn up a smaller wheel, put a groove in it also, and screw it on to the end of the iron spindle; it could then be run with a band. It works very well, however, with the wheel fixed against an indiarubber-covered knob, as previously explained.

It is preferable to substitute gun-metal for the brass in all parts except the covering and nose-piece.

CHAPTER X.

MANIPULATING STEEL AT THE FORGE.

From the foregoing chapters it will have been seen that pure metallic iron has but little commercial use, and, in fact, in this state is comparatively unknown; it is when combined with carbon, sometimes modified by other elements, that pure iron becomes the iron of commerce, and is known as malleable iron, steel, and cast iron, as the proportion of carbon is increased. The great value of steel for toolmaking consists in a characteristic, possessed by no other substance, of becoming intensely hard when quickly cooled after it has been heated to a certain temperature. The pure, the mild steels, that nearly approach the condition of iron are ductile and weldable. On the other hand, their capacity for hardening and tempering diminishes with the comparative absence of carbon, which is the principal hardening element, though in no case does the proportion equal that in cast iron. In steel, carbon seldom amounts to more than 1.5 per cent. It is less than .1 per cent in the mildest plates.

In addition to carbon, but in a lesser degree, manganese, phosphorous and silicon are hardening constituents of steel. Within certain limits, the more these constituents are present, the lower the temperature of the cooling liquid employed, and the greater its power of absorbing heat, the more intense will be the hardness induced in the steel. Mushet steel, used for making turning tools, is produced by the addition of wolfram or tungsten, in the form of a metallic alloy, to steel. The resulting alloy is so

hard that it does not require to be hardened by the tool maker.

There is, as regards chemical composition, very little difference between wrought iron and some of the mild steels. But when working there is a very essential difference between them. Wrought iron is never perfectly homogeneous, whilst mild steel is of the same character throughout. This difference is due to the altered condition in the processes of manufacture. The fluidity of cast iron is mainly due to the presence of its carbon, and in a lesser degree to its sulphur. These are removed from the iron in the processes of puddling; and one important result is the non-fusibility of the wrought iron at the temperature at which it is found best to work it. Wrought iron is never in a state of absolute fusion at any time during the process of its puddling. It is simply brought into a pasty condition, like a lump of dough. In order to render this material more homogeneous, the pasty mass is compressed under steam hammers or tilt hammers, and is passed beneath squeezers of different types, is cut up again and re-heated, and the operations of hammering, squeezing, and rolling are repeated, the homogeneous quality of the iron improving with each repetition of these operations. These sets of operations will be repeated three or four times in the case of good merchantable iron, and it is the cost of fuel and labor involved which renders wrought iron so much more costly than cast iron.

After the last piling, re-heating, and hammering processes have been gone through, the iron is run between grooved rollers of diminishing sizes, to impart the final sectional forms to the bars or plates required for the use of the smith. But even in the best wrought iron, owing to the absence of fusion, some of the oxide or scale, and some of the impurities originally present in the iron, or taken up in the process of puddling, become mechanically mixed with,

and remain in the bars, which always remain laminated, causing the iron to become spilly, and to develop incipient fracture when wrought into structures. The best wrought iron can never be depended on entirely for absolute homogeneity. But for the average work of the smith it holds its own, because of its ductility, weldability, and the general ease with which it can be fashioned into intricate forms.

The Bessemer and Siemens steels are free from this lamination, because during the process of fusion all scale or oxide is expelled; this is one reason why the mild steels have superseded wrought iron largely for boiler-makers' work, and for cranks and similar structures, where lamination would be fatal to strength and durability.

Steel being homogeneous—that is, having no lamination—is eminently adapted for forging light and delicate work, where strength, rigidity, and lightness are required in combination. While wrought iron can be worked almost at the fusing point, each different sample of steel seems to work best at a particular temperature, differing from that of other samples, but never beyond a full red heat. Steel takes a much higher polish than wrought iron, and is therefore better suited to work where good finish is necessary.

Whether steel is more troublesome to work than iron depends on the nature of the forging and on the quality of metal. For small model work, steel is by far the easier, because there is no grain to open out, besides the superior rigidity, and so forth. In large and heavy forgings there is no advantage to be gained on this score. Steel forgings of moderate size and thin sections have to be worked at a lower temperature than iron, so a larger number of heats must be taken in the former than in the latter. For the same reason the various operations should be performed more rapidly while the steel retains its heat.

There is more initial difficulty in welding steel

than iron, due to the differences in various samples of steel. Once the best welding heat for any bar of steel is known, there is no more trouble experienced in welding pieces from that bar. Sand alone is used as a flux for welding iron; for steel a mixture of sand and common salt is better.

There is a greater difference of opinion as to the working of steel than there is in regard to the working of iron. The practice of allowing steel to soak in the fire, approved by some, is denounced by others. The temperature to which steel can be raised without burning it is also a matter of dispute. The practice of hardening and tempering steel opens up an unlimited field of discussion. The reasons are that steels vary in quality much more than wrought iron, and since the peculiar value of steel is due to its chemical and molecular composition, slight differences in which cause great changes in the material, and as even slight and sudden alterations in temperature are sufficient to entirely change their arrangement, it is easy to understand why, though not how, the practical working of the material is affected. Partly because of these differences and consequent differences in treatment demanded, some makes of steel are considered superior to others. Thus, a man accustomed to work in one quality mainly, and having adopted certain modes of treatment with the best results, may find the same modes do not give equally good results with another quality; he may then condemn the steel, when in reality the fault lies in wrong treatment. Every bar of new steel should be worked tentatively in order to discover the best heat and the best way to work that particular brand. Unless this is done, failure to obtain the best results will frequently follow. The practice of upsetting steel is deprecated by some. But if the steel is of good quality it will upset just as well as iron.

Steel should be made as hot as the metal will safely

bear, but it must not be overheated, or it will become burnt. A higher temperature can be used on steel required for large forgings than for steel used for light work generally, and for cutting tools. Burnt steel under the hammer will crumble to pieces as though it were cast iron, and will show a coarse granulated fracture. There are, however, degrees in burning; the steel may be burnt only slightly on the surface, so slightly that it does not fracture, or, if fractured, does not show this coarsely crystalline structure; yet its quality for cutting instruments will be sensibly impaired. The temperature at which overheating occurs varies, of course, with different qualities. If scales form and fall off, the steel is, as a rule, overheated. It is then almost impossible to restore its quality. If not burnt very badly, a good hammering on the anvil will improve it considerably.

Steel, even more than iron, should be turned around in the fire to keep the heat uniform. The blast should be slackened after the edges have become red-hot. A full cherry-red is usually considered the proper heat for forging—but this expression is rather vague, and the temperature will vary with different qualities. Hammering should not be continued after the steel has lost its redness.

There is a temperature in steel corresponding with what is termed in iron a "black heat"—at which it is not safe to work it. Experiments show that a steel plate heated, and allowed to cool, suffers no diminution of strength, but that while cooling, and while at a blue heat, any hammering or bending seriously injures the metal. The blue heat corresponds with any temperature between about 470° and 600°.

Steel used for making tools is classified according to the percentage of carbon it contains, to which the following list is a guide. *Razor temper steel* (1½ per cent carbon) is so easily spoilt by being overheated

that it can be worked only in the hands of a very skilful workman. When properly heated, it will do twice the work of ordinary tool steel for turning chilled rolls, etc. *Saw-file temper steel* ($1\frac{3}{8}$ per cent carbon) requires careful treatment, and although it will stand more heat than razor steel, should not be heated above a cherry red. *Tool temper steel* ($1\frac{1}{4}$ per cent carbon) is the most useful for turning tools, drills, and planing-machine tools, and it may be forged by ordinary workmen. It is possible, with great care and skill, to weld cast steel of this temper. *Spindle temper steel* ($1\frac{1}{8}$ per cent carbon) is very useful for circular cutters, large turning tools, taps, screwing dies, etc. This temper requires considerable care in welding. *Chisel temper steel* (1 per cent carbon) combines great toughness in the unhardened state, with the capacity of hardening at a low heat. It is consequently well adapted for tools when the unhardened part is required to stand the blow of a hammer without splitting, but where a hard cutting edge is required, such as cold chisels, hot setts, etc. *Sett temper steel* ($\frac{7}{8}$ per cent carbon) is adapted for tools, such as cold setts, the unhardened parts of which have to stand very heavy blows. *Die temper steel* ($\frac{3}{4}$ per cent carbon) is the most suitable for tools of which the surface only is required to be hard, and where the capacity to withstand great pressure is of importance, such as stamping or pressing dies, boiler cups, etc. The last two tempers may be easily welded by a mechanic accustomed to work cast steel.

The process of hardening, as commonly understood by smiths, means the heating of a piece of steel to redness and quickly plunging it into a cooling liquid, usually either water or oil. Hardening steel often causes it to crack and warp. On immersing the steel into the cooling medium, the outer covering is rapidly cooled off first, and shrinks upon the interior.

The shrinkage puts the outside in tension. Presently the interior cools, but it is prevented from free shrinkage by its union with the exterior, and is thus itself put in tension. Then one of two things may happen: either there will be a condition of permanent tension, productive of warping or curvature, or the stresses will find relief in fracture.

Steel that is heated to redness and allowed to cool slowly is said to be annealed. Steel may be annealed by making it red hot and allowing it to cool between hot cinders. Or it may be left in a low fire until the fire has gone out and the cinders have become cold. Or it may be enclosed in a box with charcoal powder, raised to a red heat, and allowed to become cold. By hardening, steel is made intensely hard, by tempering it is made softer and less brittle, but yet it remains very hard; by annealing, it is brought into its softest possible condition.

The principal hardening agent is cold water; salt water, lukewarm water, and oil are sometimes used. Mercury is also very efficient, but its expense precludes its use for ordinary work, and for most purposes pure cold water only is used. For light and delicate work oil is generally considered preferable, and it is customary to use oil or tallow in preference to water for all delicate work. In order to lessen the liability to curvature, long narrow articles are immersed perpendicularly instead of horizontally or diagonally in the fluid, so that its effect may be evenly distributed over the whole of the surface. Steel is apt to crack if it is taken out of the water before being thoroughly quenched, or if the water level is kept at one place; it should therefore be moved slightly up and down in the water. When dipping an article of unequal thickness on the edges, the thicker edge, as a rule, should be dipped first, to lessen risk of cracking. Smiths have an opinion that water which has been long used is preferable to fresh

water, so they do not change the water in their hardening tanks, but simply add sufficient fresh to make up for waste. This preference may be due to the fact that warming of the water by immersing red-hot metal drives off the air contained in it, and allows the fluid to come into more intimate contact with the surface of the steel. The belief that boiling the water for hardening steel is an improvement may be explained in the same way.

It is not necessary that hardening should always be done in a liquid. A thin heated plate placed between two pieces of cold metal will become hardened as effectually as if immersed in water or oil. This is often done, because it tends to lessen risk of warping in a plate.

Hardening by means of hammer blows is of occasional service to increase the elasticity and hardness of a plate or lamina of steel. Its effect is similar to that of cold rolling and wire drawing, and is removed by annealing. If hammer hardening is prolonged too far the metal is fractured; annealing must therefore be resorted to before this stage is reached. The range of temper obtainable in hammer hardening is not great, and it has a limited value, being confined chiefly to laminated springs.

Tempering means that the hardened steel is slightly re-heated, and when at a certain known temperature, indicated by a shade of color which appears on its brightened surface, it is plunged into a cooling liquid, or in some few cases is allowed to cool gradually in air. This heat for tempering differs in almost every variety of tool or piece of mechanism. The tints through which steel passes from the lower to the higher temperature are straw, gold or yellow, chocolate, purple, violet, and blue. The greatest hardness and elasticity combined is obtained by tempering at a straw color. Hardening by quenching at a red heat makes a tool intensely hard, but brittle.

Tempering by quenching at a blue makes it elastic, but soft. Between these extremes lies the whole practice of hardening and tempering.

All cutting tools of the same type are not tempered alike. Thus, a tool for working hard cast steel will be tempered harder than one for working gray cast iron. A tool tempered a straw color is harder than one tempered a blue; so that if tools for hard steel are tempered to a straw, those for soft iron and brass are tempered at a tint approaching purple.

As an example of hardening and tempering, a cold chisel is the tool selected. The scale is removed from the surface, and its cutting end, to the length of about a couple of inches, is then first heated to a cherry red in a clear fire, afterwards quenching in water, and thus hardened. It is taken out and rapidly brightened with a bit of grindstone or emery, in order that the rapidly changing hues may be observed the better. The cooling of the end only lasts for an instant, as the heat of the shank at once raises the temperature of the end for tempering, until the instant arrives at which it must be quenched. The smith then plunges the entire chisel into the water, moving it to and fro until quite cold. The color for tempering in the case of a cold chisel is a deep straw inclining to purple, but, of course, the color will vary with different grades of steel.

Another way of tempering small tools is to heat to redness in the forge fire a bar of iron, and lay the tools upon it until they reach the color required, and to then quench them. If the bar is made red hot at one end only, the tools can be gradually slid along toward that end and so slowly heated thoroughly through, until they reach the precise tint desired for tempering.

A bath of molten lead is a good heating agent for articles that are of unequal thickness; these can thus be heated uniformly. The lead is prevented from

oxidation by covering its surface with powdered charcoal. The temperature of a bath of molten metal is, of course, uniform, and by making alloys of lead and tin in various proportions, an extensive range of temperature is obtainable. The table below serves to show what range can be got by such tempering baths.

Drills for cutting iron are tempered to a dark straw at the cutting edges. The remarks made in reference to the hardening and tempering of a cold chisel apply equally to drills for iron. Drills for hard steel are heated and quenched in a lump of lead, and not tempered afterwards.

Axes are hardened and tempered very much like chisels. They are heated first to redness, and quenched in water to a depth of two or three inches. A face is polished, and the changing tints observed until the appearance of a deep blue, when total immersion is made for temper. As for other tools, different shades of blue, inclining towards a brown straw, will be required for different grades of steel.

TEMPERING STEEL.

<i>Color.</i>	<i>Articles to be Tempered.</i>	<i>Composition of the Bath</i>		<i>Temperature in degrees Fah.</i>
		<i>Lead.</i>	<i>Tin.</i>	
Yellowish tint.	Lancets	7	4	420°
	Other surgical instruments	7½	4	430°
	Razors, etc.....	8	4	442°
Pale yellow...	Penknives, and some implements of surgery	8½	4	450°
	Straw yellow..Larger penknives, scalpels, etc.....	10	4	470°

Color.	Articles to be Tempered.	Composition of the Bath.	Lead.	Tin.	Temperature in degrees Fah.
	Scissors, shears, garden hoes, cold chisels, etc.		14	4	490°
Brown yellow.	Axes, firmer chisels, plane irons, pocket-knives, etc.....		19	4	509°
Light purple..	Table-knives, large shears, etc.....		30	4	530°
Dark purple..	Swords, watch-springs, etc.		48	4	550°
Clear blue....	Large springs, daggers, augers, fine saws, etc.		50	2	558°
Pale blue.....	Pit saws, hand saws, and some springs....	Boiling linseed			
Greenish blue.	Articles which require to be somewhat softer	Molten lead.			600° 612°

Mill picks are hardened only, and not tempered. They are heated to a dark red, and quenched, the temper thus obtained not let down, as is the case with most of the tools already noticed. Pure soft water is quite suitable for these, though some smiths use mixtures of salt, alum, sal-ammoniac, etc.

Springs are hardened in the usual way by heating to a cherry red, and quenching in water. Then they are smeared with tallow or lard, and heated over the fire, moving them to and fro until the tallow catches fire, and blazes and burns off. The springs are then laid upon the forge, or in the ashes to cool down. If the work is of irregular thickness, the burning of the oil should be repeated two or three times. Small springs made in quantities are often

put into a sheet-iron pan and covered with oil, and held over the fire until the oil blazes and burns off. Moving and shaking the pan about causes the temper to be more uniform. In the case of heavy springs the operation may be repeated two or three times.

Screw taps are conveniently heated in an iron tube, large enough to allow not only of the admission of the tap, but also of the tongs by which it is held. The tap is first heated gradually and very slowly, and equally throughout, to a dull red in the tube. If heated rapidly, the edges of the threads will be made hotter than the interior, and being too hard, will probably crumble off in use. It must be an invariable rule to harden and temper taps at the lowest heat practicable. A dull red must not be exceeded. It is better to make two or three attempts, increasing the heat each time, rather than to overheat the tap, which is plunged vertically into water and held there until quite cold. Afterwards the flutes are brightened and the tap heated in the tube to a light straw. Some use linseed oil baths for hardening taps and dies. The points of the threads will be protected if coated with soft soap, or with a paste made of prussiate of potash and flour, or yeast.

Screwing dies are heated to a cherry red, and hardened in salt water. To diminish the risk of cracking, they may be covered with prussiate of potash or with a paste of soap and oil. The faces are polished, and to temper them the dies placed on a piece of hot iron, taking care to turn them over and over until they are of a straw color. A bath of linseed oil may be used for cooling. Worn dies are, as a rule, re-cut, but before this can be done, the temper must be completely drawn by annealing the dies by heating them to a light cherry red in a clear fire and allowing them to cool slowly. Other tools, such as broaches, milling cutters, reamers, and lip drills, when worn, are similarly annealed preparatory to re-

cutting. Afterwards they are hardened and tempered just as in the case of new tools.

Case hardening is a method commonly used for rendering the surface of wrought iron as hard as tempered steel. Case hardening means that just the outer skin of iron is hardened, and made of the nature of steel. Only wrought iron can be treated thus. A mere film of surface hardening may be effected by heating the iron red-hot, rolling it in powdered yellow prussiate of potash, and quenching in water. When the hardening is required to extend to a greater depth, the work is enclosed in an iron receptacle along with leather clippings, bones, horn, and yellow prussiate of potash, and heated for from twenty to forty hours. The work is then cooled in water. The advantages of case hardening are that the toughness of the wrought iron is combined with a durable wearing surface as hard as steel; and that the first cost of the forgings, and of the cost of their being tooled and finished into shape, is less than the cost of steel forgings. Case hardening is adopted in link-reversing gear for engines, for the eyes and working faces of levers, for pins or pivots, and so forth. To case harden at the forge, have ready a quantity of yellow prussiate of potash powdered very fine in an iron tray. Heat the work in the clear fire to red heat and with a spoon strew thickly over the surface of the forging, and, if practicable, roll the forging also in the potash. The work is re-heated and time given to allow the powder to fuse and run freely over the surface, then the forging is quenched, and this hardens it.

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